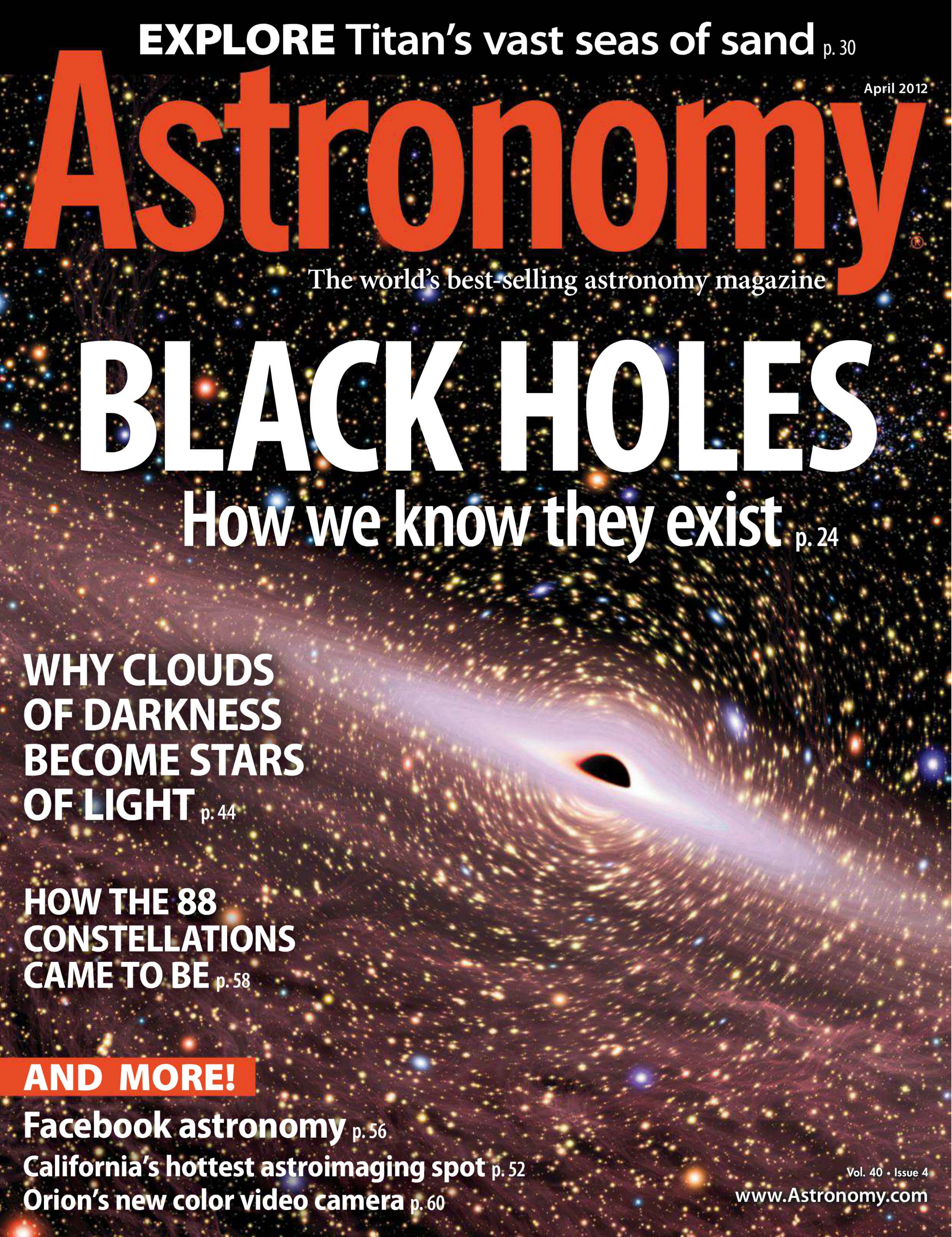
EXPLORE Titan's vast seas of sand p. 30

Astronomy

April 2012

The world's best-selling astronomy magazine



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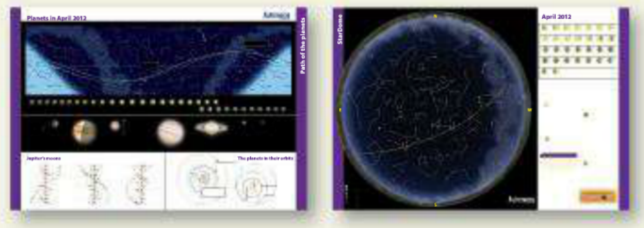
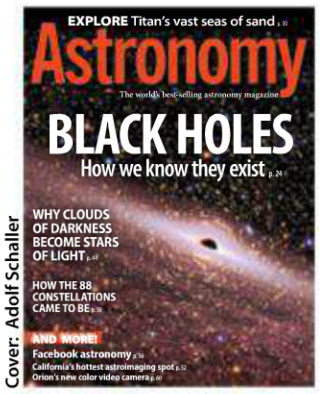
Path of the planets and StarDome center spreads



Southern Hemisphere maps at the end of issue



Cover: Adolf Schaller

ON THE COVER

Astronomers have collected a vast amount of evidence over the past 50 years about black holes. They can now say that these objects exist.

April 2012

COLUMNS

IN EVERY ISSUE

WEB EXTRA

Visit **Astronomy.com/toc** for bonus material — it's exclusive to *Astronomy* magazine subscribers.

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This Month in *Astronomy*

So what's the deal with black holes?

by David J. Eicher

Black holes are certainly some of the strangest inhabitants of the universe. Scads of research center on them on all scales — from micro black holes a tenth of a millimeter across that could contain the mass of the Moon to supermassive black holes in the centers of giant galaxies. The largest span a few times the distance between the Sun and Pluto and contain the mass of a billion Suns.

When I joined *Astronomy*'s staff in 1982, black holes were, scientifically, little more than a rumor. Although they were hypothesized by English geologist John Michell in 1783, no one had any concrete evidence for black holes until the Hubble Space Telescope started doing its thing in the 1990s. From concept to proof, that's quite a long gestation period, even for exotic scientific ideas.

So just what are black holes, and why did it take so long to find one? This is the subject of Associate Editor Liz Kruesi's story "How we know black holes exist" (p. 24). Put simply, black holes are regions of space-time in which gravity is so strong that nothing, not even light, can escape. The "surface" of a black hole is its "event horizon," the dividing line between slipping into eternal nothingness or remaining in the universe the rest of us know and love. Black holes are called such because they are perfect thermodynamic black bodies, reflecting nothing that strikes them. And that's what gives them their mystery.

The universe is a curious thing, and black holes form for a variety of reasons. Astronomers used to believe that so-called active galactic nuclei — galaxies with black holes in their centers — were rare creatures. Now, they know that virtually all normal galaxies (excluding dwarfs) have black holes in their centers. The quiet ones are quiet because the black holes don't have handy "food" (gas and dust) to wake them into a feeding frenzy that would emit huge amounts of high-energy radiation.

Stellar-mass black holes form in the wake of supernova explosions — from stars at least 20 times larger than the Sun — and populate galaxies with orbiting regions that would cause major troubles for interstellar travelers. (Sorry, sci-fi fans, but traveling through a black hole would be no fun for living things. Even if you could find a "wormhole" to travel through to another part of the universe, the journey into it would pull you into a string of protons.)

Black holes could arise from other sources, too, like primordially in the early universe. No one as yet knows which came first — black holes, stars, or galaxies. That's a major area of research that interests astronomers and cosmologists every day.

Because they cannot be seen and do not emit energy, detecting black holes means observing their effects on other things near them. Kruesi's story will guide you through the evidence astronomers have for their existence. Although we've suspected the existence of these strange creatures for 229 years, astronomers are just now getting to know them.

Yours truly,

David J. Eicher
Editor

Astronomy

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Letters

Shooting lightning

Stephen James O'Meara's column "Capturing the night's 'flying flames'" in November's *Astronomy* was very informative. I have been trying for several years to get "that shot" of the elusive lightning bolt. I read article after article online and reviewed a bunch of lightning photos, but I never could get it. None of those resources were as concise and helpful as O'Meara's two-page column.

I'm just glad that after all my studies, my settings were close to what he prescribed in his urban guideline. I found that shooting at ISO 100, f/14, and the correct shutter speed (metered off the sky) to match the settings rendered pretty decent photos. I can't wait for the next storm so I can try what O'Meara said (backing the f/stop down to f/8 or f/11). I'm sure the photos will come out even better! — **Frank Garcia,** Broussard, Louisiana

Lightning flashes across Frank Garcia's urban setting. He followed Stephen James O'Meara's November column to capture this shot.

Seasoning is just as important

As always, I found Bob Berman's October article, "It's element-ary," great food for thought. However, I think we owe more to the remaining 87 known elements than to call them "an extravagance" or "seasoning." Berman notes that "Argon doesn't even *help us think*, unlike hydrogen and oxygen, which is what nature mostly constructed our brains out of." But hydrogen and oxygen don't really help us think, either.

A living brain operates thanks to a complex molecular and electrical exchange that is mostly reliant on elements not named in the article: potassium and sodium (chlorine plays a lesser role). So the next time you top your food with some salt or eat a banana, remember that without "element-ary seasonings," your brain or mine would be no different than the one soaking in a jar in an anatomy classroom. — **Jay Michaels,** Florida Atlantic University, Boca Raton

Observing for all

Kudos to Michael E. Bakich on a great article in the December issue, "Wander winter's deep sky." In it, he addressed targets for telescopes ranging from 3 inches to 20+ inches. What a great idea for saving a lot of time and frustration for us owners of smaller scopes and helping us eliminate targets that are simply beyond the capabilities of our instruments.

I hope this format will be followed in future articles with targets for the other three seasons. — **Bert Probst,** Bay Village, Ohio

Thanks for the kind words. I'm glad you found the story helpful. Your note, along with others I've received, just might tip the scales toward us producing similar ones for other seasons. Stay tuned. — **Michael E. Bakich,** Senior Editor

Oh, satellites

On a crisp fall morning last year, as dawn was presenting itself, I looked near Jupiter with my 7x50 binoculars. Something moving caught my eye. I put down the binoculars and could still make it out.

I've seen many meteors and thus knew this object couldn't be one. Perhaps it was a satellite? I was puzzled, though, because it seemed to disappear as it moved northwest, yet the Sun was rising in the east. I expected to be able to continue viewing the satellite as it moved toward a darker part of the sky.

Stephen James O'Meara's September column explained what happened — the satellite passed into Earth's shadow and no longer reflected light. — **Don Francis,** Lakewood, New Jersey

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; email to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Web Talk

What's new at Astronomy.com. **by Karri Ferron**

Astronomy 101

Science basics on video

If you're just getting into astronomy, you might need an intro course to explain all the basic objects and concepts of the field. Look no further than the *Astronomy 101* video series for fun lessons that are easy to follow.

With each quarterly episode, Associate Editors Bill Andrews and Liz Kruesi help viewers understand the intriguing objects and concepts that make up the cosmos. *Astronomy 101* and its sister series, *Cosmology 101*, have covered everything from galaxies and nebulae to the Big Bang and black holes; each video includes discovery information, formation processes, and the latest research news. Get a grasp on the basics in no time by visiting **www.Astronomy.com/101**.

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OBSERVING TOOLS

Celestial Portraits

Astronomy's editors have compiled a series of 11 digital packages called "Celestial Portraits" for observers to purchase and download. The collection highlights all 88 constellations and explains how to observe the deep-sky targets within each one. Each package contains four articles with easy-to-read star charts, tables with detailed deep-sky object information, beautiful images from amateur astroimagers, constellation mythologies, and more. Download a free preview of Orion the Hunter at **www.Astronomy.com/portraits**.

COMMUNITY


Lynn Hilborn

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Strange**Universe**

by Bob Berman

Messing up

This April holiday is a time to look back on my astronomy follies.

April Fool's Day makes me recall the times I've been a fool — an astronomy fool. I'll limit this confessional to that category due to lack of space.

It comes to mind because of a review of my book *The Sun's Heartbeat* (Little, Brown and Company, 2011) that appeared in *The Wall Street Journal* (*WSJ*). The reviewer recommended it, but he also claimed it had many small errors, which simply isn't true. The critic, John Gribbin, griped, "The formation of the sun is described as occurring in a 'plain-vanilla' cloud of hydrogen gas; the cloud was roughly 25% helium." I stared in disbelief. It was true I first mentioned only hydrogen. But on the next page, and then again and again, I included the helium. Had he even read the whole thing? And he kept doing that.

What was going on here? I stared at the reviewer's name. Gribbin. It seemed familiar. Suddenly I remembered. He was in *The Sun's Heartbeat*. I'd called him "discredited" because he'd claimed earthquakes would destroy California in 1982 due to a planetary alignment.

He was the only astronomer I criticized. And this was the guy *WSJ* chose to review my book. What bad luck. But maybe this was a lesson. Perhaps it's bad karma to put anyone down. Maybe I got what I deserved.

Exactly 20 years ago, on my monthly page in *Discover* magazine, using information in Guy Ottewell's Astronomical Calendar, I said the 1998 solar eclipse would be total over the Caribbean island of St. Kitts. Years later, a reader wrote to us. He'd planned his vacation around the event. He'd trusted me. Turned out, the eclipse was *not* total from there. Ottewell had been wrong, and I'd been a fool to rely on a single source and not check my facts more thoroughly.

Also foolish is to hold myself up as an expert in celestial pronunciation. I've spent years drilling into my brain how to correctly utter the constellations and stars so not to spread falsity during lectures or TV shows. It bothered the heck out of me when the characters in the movie *Contact* pronounced Vega as "VAY-guh." Actually, the name was originally WEE-guh, meaning a falling eagle.

But in several respected dictionaries, VAY-guh is now listed as an acceptable alternative to the preferred VEE-guh. A few even claim it's OK to say "Yur-AIN-is" instead of the classical "YUR-uh-nus." How can they do that to the god of the sky? Won't they get smitten?

How many readers made a purchase based on my flawed advice?

Widespread mispronunciation has also made a few dictionaries decide it's now OK to say TRAN-see-ent instead of TRAN-shent when you mean something ephemeral like a meteor. And because everyone now seems to say "He's a CON-suh-mit pianist" instead of the correct "cuhn-SUM-it," I expect this widespread, irksome mispronunciation will eventually get an official green light, too (if it hasn't already). Language evolves.

Astronomy language is no exception. Which means I'd be a fool to keep wincing when others say BEE-tel-jooz, SPEE-ka, MEE-ra, and HAY-leez Comet (instead of the preferred BET-el-jooz, SPY-ka, MY-ra, and HAL-eez or HAWL-eez). If you're going to make people self-conscious about uttering celestial names, you might be doing more harm than good.

I also used to snootily state that only binoculars with large 7mm exit pupils (a binocular's second number divided by the first, such as 7x50s) were worthwhile for astro-use because they produce the brightest images. But that's not necessarily true. After age 30 or so, few people have pupils that can still dilate to 7 millimeters, so the light is wasted. Meanwhile, such optics create an unpleasant milky background unless skies are *truly* dark. Plus, they're heavier and thus discourage lengthy use. How many readers made a purchase based on my flawed advice? In truth, to obtain good low-light brightness for older observers, the optimum exit pupil is probably around 5mm, like in a 7x35 model.

Nor are my foolish years necessarily over. This past September 30, I failed to check my appointment book. The phone rang; it was the studio, 100 miles away: "What happened, Bob? You're scheduled to do a live one-hour call-in show! … OK, we'll patch you in over the phone. … You're on in three minutes."

Unfortunately, a half-hour later, just as a caller is asking about possible nearby supernovae, a FedEx truck pulls in front of the house. My yappy dog goes crazy, and I can't shut her up. My sophisticated exposition is seemingly taking place at the pound. A quarter-million people then hear the guy knock noisily. I give him the "shhh!" gesture, making eye contact while loudly saying, "Betelgeuse is too far away to destroy us," into the cordless. He's puzzled, but hands me a device to sign as I struggle to remember my chain of thought while people in six states hear Walnut going "grrrrrr."

I won't even get into my youthful idiocies, like sweeping a telescope near the Sun to look for Venus at inferior conjunction and accidentally getting a blast that could have easily blinded me. Or, or . . .

Yes, I should pop a cork every April Fool's Day.

Contact me about my strange universe by visiting **http://skymanbob.com**.

Browse the "Strange Universe" archive at www.Astronomy.com/Berman.

Observing**Basics**

by Glenn Chaple

Celebrate an astronomical holiday

April 28 is a great day for a public star party.

Circle April 28 on your calendar. On this date, countless millions of people will look to the skies in celebration of Astronomy Day.

Alright, so I exaggerate. Astronomy Day isn't exactly a major holiday, and you'll be hard-pressed to find Astronomy Day cards. But to thousands of enthusiasts, Astronomy Day rivals New Year's Day in importance. It's a time when we pay due respect to a noble science and share our passion for backyard observing with the public. In the process, we hope to recruit some newcomers to our ranks.

What better way to accomplish that goal than with a public star party? For those of you planning such an event (if you're a member of an astronomy club, make this a priority!), here are a few pointers to help ensure yours is a success.

Plan a star party around the time of First Quarter Moon. There's a good reason why Astronomy Day coincides with this lunar phase. Our only natural satellite may be a pain in the butt for those of us trying to detect 14th-magnitude galaxies in an already light-polluted sky. John or Joan Newcomer, however, won't be impressed if he or she is greeted by a faint smudge of light when peering into the eyepiece. But give them the Moon? Wow! Unbelievable! Fantastic!

Besides the "wow" factor, there's another important reason for including the Moon on your star party menu. A first-time telescope viewer often has difficulty making the eye-to-eyepiece connection. At star parties held on dark-sky evenings, I've seen people struggle to glimpse non-lunar targets like Jupiter or Saturn. The Moon, on the other hand, lights up the eyepiece, guiding the viewer to the "sweet spot." Later in the evening, when a planet or bright deep-sky object is in the telescope's field of view, the newcomer will have an easier time seeing it.

Impress your audience with the wonder of the night sky, not the magnificence of your equipment. I once brought a 4.5-inch reflecting telescope to a star party dominated by large, expensive telescopes. Nobody bothered to stop for a look through my puny little scope; I had to virtually beg passers-by to take a peek. Once they did, however, they were amazed at how much they could see through such a small and inexpensive instrument.

The novice whose first and only backyard astronomy experience is via a huge high-tech telescope will assume that backyard astronomy is a hobby enjoyed by only the wealthy and technically proficient. Show that person the Moon's cratered surface or Saturn's rings with a no-frills 4- to 6-inch reflector that costs less than a laptop, though, and your local astronomy club just might get a new member. By all means, bring the "big guns" to your star party, but plan on adding at least one modest-sized telescope to the mix.

Astronomy Foundation

Simple telescope setups at public star parties make the hobby accessible for newcomers.

And don't forget to have binoculars on hand. If you think neophytes are surprised by the capability of small telescopes, wait until they see the Pleiades (M45) through binoculars. Dust off those binoculars sitting in your closet to serve a newfound purpose.

If possible, start the star party with an explanatory talk. It helps to present a brief but informative introductory twilight talk before heading for the telescopes. Include a rundown on the evening's observing "menu," a demonstration of how to look into a telescope eyepiece, and some "star party etiquette"— especially if a number of youngsters are present. Caution them about running around, using bright flashlights (or even cellphones), hogging the eyepiece at the expense of others waiting in line, and (very important) sticking their faces in front of a telescope while someone is peering into the eyepiece! Above all, make sure everyone feels comfortable asking questions, no matter how silly they might seem.

Offer handouts that introduce astronomy to the beginner. At the very least, have available a resource list that includes recommended guidebooks and publications (like *Astronomy*!), a way to contact your astronomy club or local amateur astronomers willing to serve as mentors, and the URLs of beginner-friendly websites. Astronomy clubs should also consider *Astronomy*'s Star Party Action Kit, which I mentioned in my January column. It contains brochures, magazines, and booklets for clubs to hand out at a *Discover the Universe* star party. See www.Astronomy.com/discovertheuniverse for more information.

Many websites offer how-to information for carrying out a public star party. San Francisco Sidewalk Astronomers member Michael Portuesi offers his suggestions at http://tinyurl.com/sfastro. Those of you planning a star party for a local school will appreciate the pointers offered by the Astronomical Society of the Pacific in conjunction with its Project ASTRO outreach program. Log on to http://tinyurl.com/ASPparty.

Astronomy Day may pale in comparison to New Year's Day, but it has one feature that no other holiday can offer: It's observed *twice* each year! Take that, New Year's! The second Astronomy Day will occur October 20. Stay tuned!

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: spring double stars. Clear skies!

Browse the "Observing Basics" archive at www.Astronomy.com/Chaple.

SecretSky

by Stephen James O'Meara

The secret of Sextans

Witness the results of divine intervention — or perhaps just imagination — among the stars.

Of all the constellations in the April night sky, one of the dimmest and most ignored is Sextans the Sextant. Polish astronomer Johannes Hevelius created Sextans Uraniae (now just Sextans) in 1687 to commemorate the large sextant he and his wife, Elisabeth, used to measure star positions. A fire, he said, consumed the instrument in September 1679 when Vulcan (the Roman god of fire) overcame Urania (the muse of astronomy).

Although ambivalent toward astrology, Hevelius thought the new constellation's celestial location seemed appropriate: It lies between Leo the Lion (a fire sign) and Hydra the Water Snake (also associated with fire). And it turns out a fire, at least of the creative kind, might have resulted in a famed historical mystery associated with the constellation Sextans' stars.

Johannes Hevelius (left) borrowed some of the stars between Leo the Lion and Hydra the Water Snake to create the constellation Sextans the Sextant, in honor of the instrument (seen here) he and his wife, Elisabeth, used to measure the stars. Stephen James O'Meara Collection

A heated imagination?

In April 1643, European observer Antonius Maria Schyrleus de Rheita claimed to have seen among the stars of Leo (those which Hevelius later turned into Sextans) the holy *Sudarium Veronicae* — the handkerchief Saint Veronica used to wipe the face of Jesus on his way to Calvary. As depicted in the Sixth Station of the Cross, the cloth then took on the impression of Christ's face. Interestingly, and perhaps tellingly, the Catholic Church's Capuchin Order, of which de Rheita was a friar, has claimed possession of this cloth since the 16th century.

Is it surprising, then, that de Rheita envisioned the cloth among the stars of Leo, the "King" of the zodiac, near the point where the ecliptic intersects the celestial equator? This is the point of the autumnal equinox, when, spiritually, the Sun begins a descent toward its own Calvary.

Certainly, we should not fault de Rheita for applying his inspiration to the stars, no more than we would Hevelius for picturing something of his personal interest in the region. But de Rheita appears to have had a colorful imagination. In 1642, for instance, he claimed that a parade of shooting stars passed in front of the Sun for two weeks, resulting in a dimming of our star's light.

De Rheita avidly pursued astronomy and optics throughout the 1640s. In 1645, he published his most famous work, *Oculus Enoch et Eliae*, in which he introduced new telescope and eyepiece designs. The work not only gave us the words *ocular* and *objective* but also the first drawing of the Moon as seen through a telescope that inverts the image. A lunar crater (Rheita) and valley (Vallis Rheita) are named in his honor.

His *Oculus* also included mention of his 1643 sighting of the *Sudarium Veronicae*, which he made through a binocular telescope of his own design — the first ancestor of today's binoculars. In the 19th century, however, English astronomer John Herschel downplayed de Rheita's sighting, saying, "Many strange things were seen among the stars before the use of powerful telescopes became common."

Stephen James O'Meara Collection

The *Sudarium Veronicae* (St. Veronica's Handkerchief) appeared to Antonius Maria Schyrleus de Rheita in April 1643, shown here in George F. Chambers' 1881 revised version of William Henry Smyth's *A Cycle of Celestial Objects*. Chambers called the figure "a Pious Fraud."

www.astrofilitrentini.it

◀ **This drawing of the Moon** through an inverting telescope was just one of the astronomical observations found in Antonius Maria Schyrleus de Rheita's most popular work, *Oculus Enoch et Eliae*.

Got the time?

If you'd like to search for this lost and forgotten asterism, Admiral William Henry Smyth said, in his 1844 work, *A Cycle of Celestial Objects*, that it lies about 9° southeast of Regulus (Alpha [α] Leonis). Later editions also included a representation of the figure, but gave no apparent size or orientation. Clearly, seeing the pattern (if it exists) won't require a "powerful telescope," but perhaps only binoculars … and your imagination.

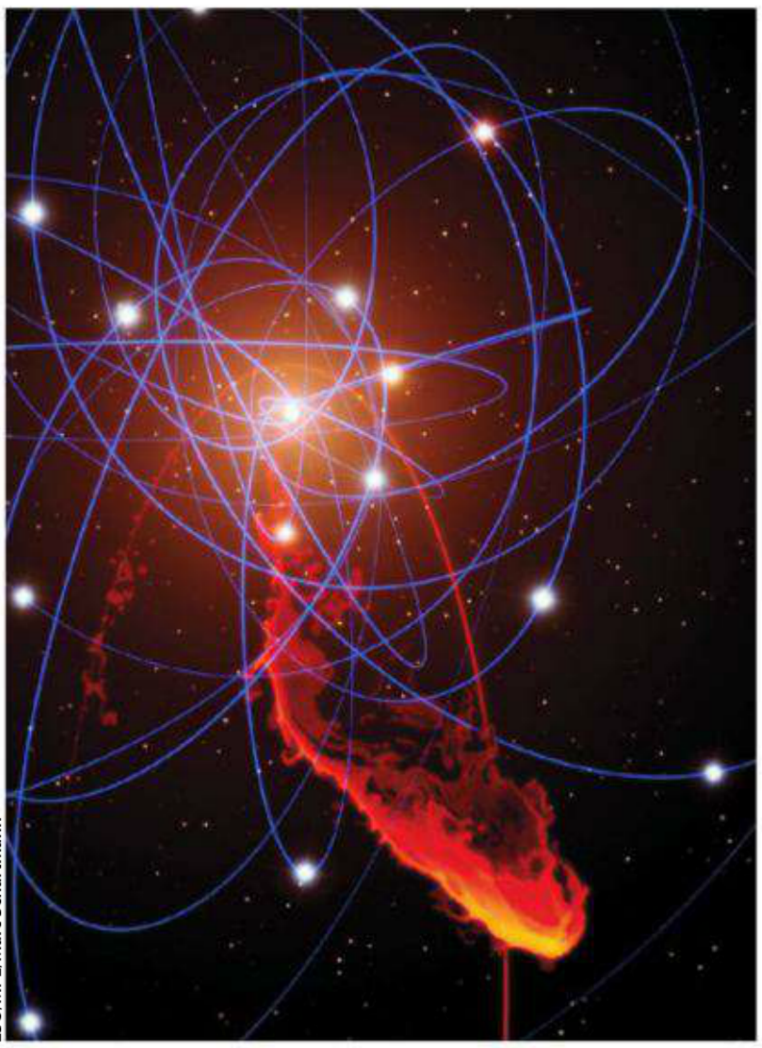
As always, let me know what you do or don't see at someara@interpac.net.

Browse the "Secret Sky" archive at www.Astronomy.com/OMeara.

April 2012 **Mystery solved** The mysterious objects known as ultra-compact dwarf galaxies are likely to be bright star clusters, according to findings in the January issue of *Astronomy & Astrophysics*.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

Astronews



ESO/MPE/Marc Schartmann

Black hole buffet. This computer model depicts the imminent breakup of a huge gas cloud on its way to the supermassive black hole at the Milky Way's center. Simulating the view in 2021, the image shows the cloud's remains in red and yellow, its original orbit in red, and the orbits of nearby stars around the black hole in blue.

Doomed gas cloud approaches black hole

Scientists are about to observe a supermassive black hole's table manners. While studying the motions of stars near the supermassive black hole at the center of the Milky Way, astronomers discovered a huge gas cloud heading directly toward it. The findings appeared in the January 5 issue of *Nature*.

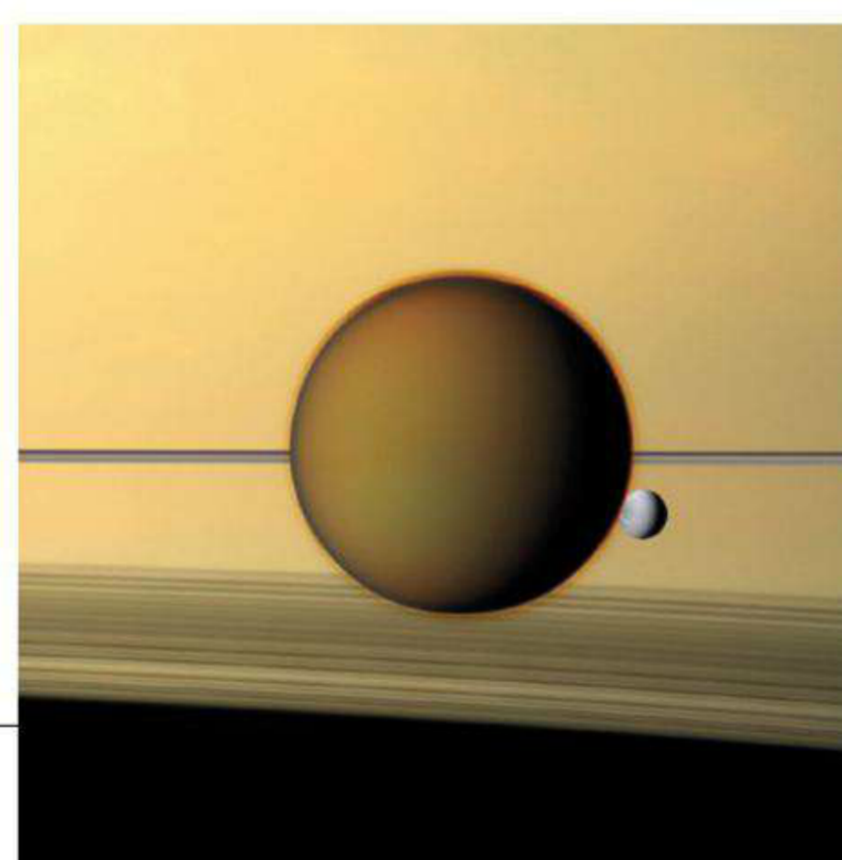
The black hole, named Sgr A* (pronounced "Sagittarius A star"), is roughly 4 million times as massive as the Sun. Its enormous gravitational strength will pull apart the mostly hydrogen and helium cloud as Sgr A* brings the gas ever closer.

"The idea of an astronaut close to a black hole being stretched out to resemble spaghetti is familiar from science fiction," says lead author Stefan Gillessen of the Max Planck Institute (MPI) for Astrophysics in Garching, Germany. "But we can now see this happening for real to the newly discovered cloud. It is not going to survive the experience."

The cloud, some three times as massive as Earth, approaches Sgr A* at about 5 million mph (8 million km/h) and will reach its nearest point to the black hole in mid-2013. Because Sgr A* doesn't have much material in its immediate vicinity, and thus currently seems quiet, the gas cloud will provide a new source of radiation as it nears and eventually falls into the black hole.

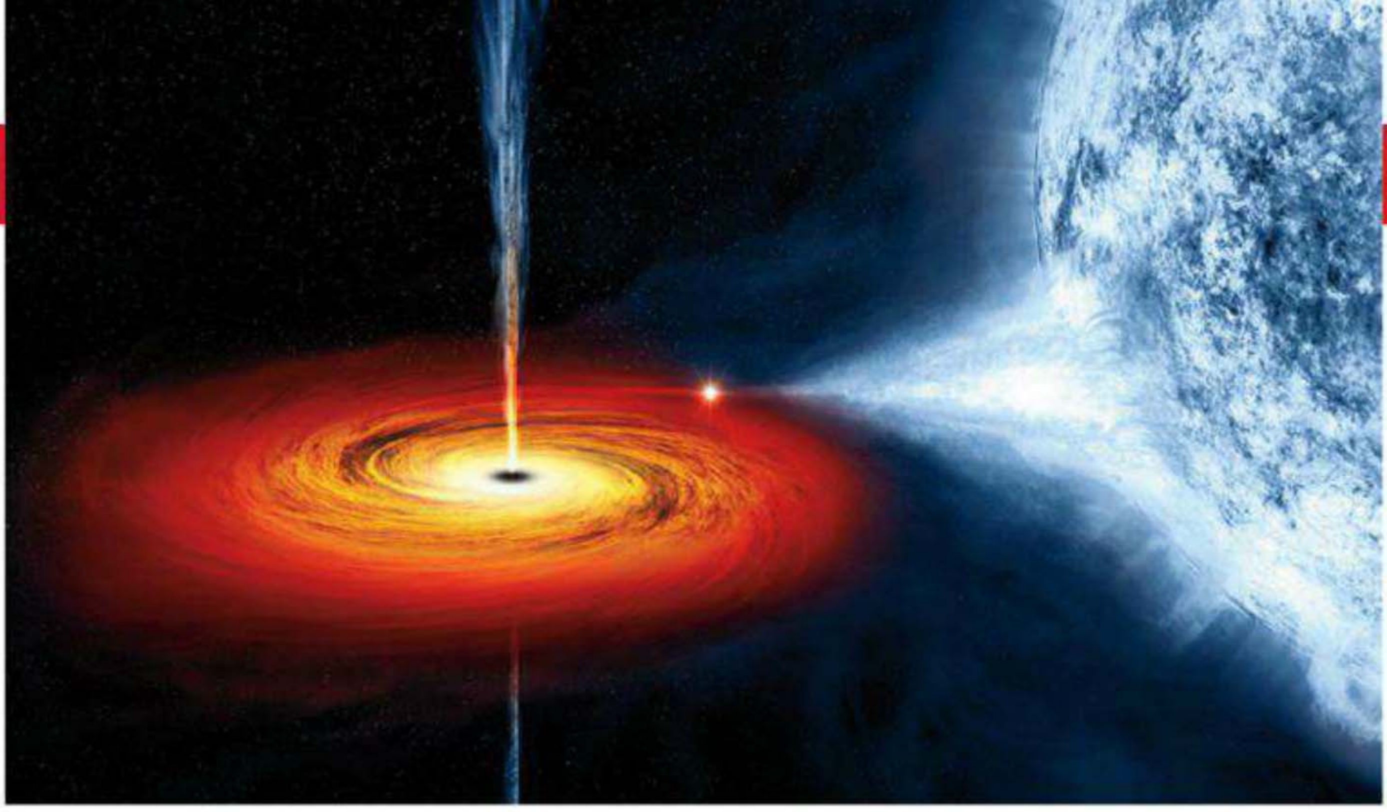
"The next two years will be very interesting and should provide us with extremely valuable information on the behavior of matter around such remarkable massive objects," says co-author Reinhard Genzel, also of the MPI. — **BILL ANDREWS**

Cassini captures multiple moons



NASA/JPL-Caltech/Space Science Institute

Picture perfect. Two of Saturn's moons take center stage in this image, released December 22, from NASA's Cassini mission. The planet's largest moon, Titan, and its atmosphere slightly overlap smaller satellite Dione, while both pass in front of Saturn's striking rings. The Cassini spacecraft was about 1.4 million miles (2.3 million kilometers) from Titan and 2.0 million miles (3.2 million km) from Dione when it captured this picture. — **LIZ KRUESI**



Black hole, nailed. Astronomers determined that the black hole in Cygnus X-1, illustrated here, holds 14.8 times our Sun's mass, spins some 800 times per second, and is 6,070 light-years from Earth. NASA/CXC/M. Weiss

Researchers learn details of Cygnus X-1's black hole

Astronomers have further verified one of the first black hole candidates ever discovered. By monitoring the bright, massive blue star in the Cygnus X-1 binary system, they determined the unseen companion's distance from Earth, its mass, and its spin. The findings appeared in three papers published December 1 in *The Astrophysical Journal*.

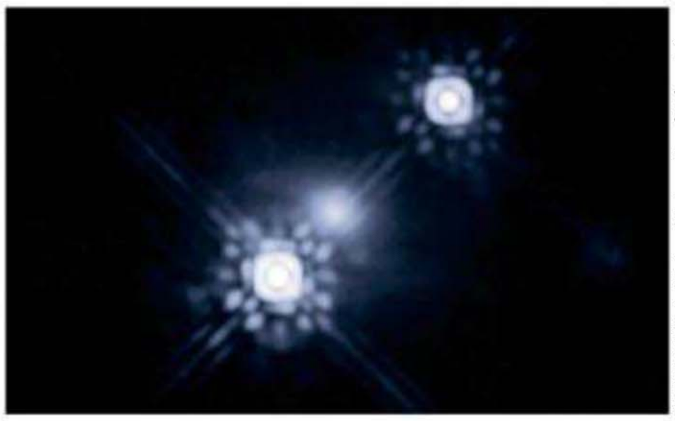
Astronomers used the Very Long Baseline Array, a continent-wide radio telescope, to achieve high-enough resolution to directly make a trigonometric measurement of the distance to Cygnus X-1. The team, led by Mark Reid of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, also determined that the binary system lies 6,070 light-years from Earth.

A team led by Jerome A. Orosz of California's San Diego State University combined X-ray and visible-light data spanning more than two decades to calculate that the system's black hole is 14.8 times the mass of our Sun. Then, a team led by Lijun Gou of Harvard used the mass and distance measurements to find that the black hole spins more than 800 times each second.

The discoveries also hint at Cygnus X-1's formation. "There are suggestions that this black hole could have been formed without a supernova explosion," says Reid. — **L. K.**

Scientists measure extremely distant quasar

Imagine using a lens so powerful that you could resolve individual grains of sand on the Moon's surface from your backyard. A study in the December 1 issue of *The Astrophysical Journal* describes how scientists have done something similar, using a galaxy as a lens to focus on a quasar billions of light-years away.



NASA/ESA/J. A. Muñoz (University of Valencia)

Trick of light. Scientists measured a quasar (the two bright shapes) in detail for the first time, thanks to the gravity of a closer galaxy acting as a lens to focus the quasar's light.

The quasar in question, HE 1104–1804, is a bright disk of matter — called an accretion disk — surrounding and slowly falling into a supermassive black hole. Typically, quasars lie incredibly far away, making it hard to observe them.

But the team, led by Jose Muñoz of the University of Valencia in Spain, took advantage of an effect known as gravitational lensing to study this quasar in detail. Because a massive object's gravity distorts the space-time around it, any beams of light traveling near the object also experience warping. When the configuration is right, this distortion can act like a lens to focus the light and make the more distant object appear clearer.

In fact, Muñoz's team exploited gravitational lensing so effectively, it could directly observe the accretion disk's size and measure the varying temperature across its surface. The team determined that the disk is between 4 and 11 light-days across, or about 64 billion to 180 billion miles (103 billion to 290 billion kilometers).

"Quasars' physical properties are not yet well understood," says Muñoz. "This new ability to obtain observational measurements is therefore opening a new window to help understand the nature of these objects." — **B. A.**

QUICK TAKES

POWITANIE, PLANETS!
The Zooniverse team unveiled a Polish version of its popular Planet Hunters project November 25, the first international version of the citizen science endeavor.

SPEAR A COMET
NASA announced December 13 that it had begun working on a harpoon that would obtain samples of comets without having to land on one.

SUPER EXPENSIVE EARTH
Super-Earths, planets up to 15 times as massive as our own, could potentially be half made up of diamond, according to research presented December 6 at the American Geophysical Union meeting.

RAD INSTRUMENT
The Radiation Assessment Detector (RAD), one of the tools on NASA's Mars Science Laboratory, began collecting data December 6 to learn what dangers a human traveller to Mars might experience.

WE'RE BAAAAAAACK
The Search for Extraterrestrial Intelligence Institute announced December 5 that California's Allen Telescope Array would again listen for alien signals among extrasolar planetary systems.

COOL NEWS
Cryogenic testing on the mirrors for NASA's James Webb Space Telescope (Hubble's successor) is now complete, the agency announced December 21.

BRAVO, FERMI!
NASA announced December 13 that its Fermi Gamma-Ray Space Telescope has shown that Tycho's supernova remnant shines brightly in high-energy gamma rays.

NO-SPIN ZONE
A study published online December 11 in *Nature Geoscience* theorizes that the planet Mercury may once have been tidally locked with the Sun before a collision with an asteroid caused its current rotation pattern.

IN MEMORIAM
Patricia Tombaugh died January 12 in Las Cruces, New Mexico, at the age of 99. Her husband, American astronomer Clyde Tombaugh, discovered Pluto in 1930. — **B. A.**

Stéphane Charpinet/Institut de Recherche en Astrophysique et Planétologie

Growing pains. **Former red giant KIC 05807616, the blue-white object in this illustration, has two Earth-sized planets in tow, orbiting closely enough to have been previously submerged within the star.**

Astronomers find two star-forged planets

Usually, something immersed in fire — or dipped into a star — doesn't survive for long. But, according to a paper in the December 22 *Nature*, two tiny planets have beaten those odds.

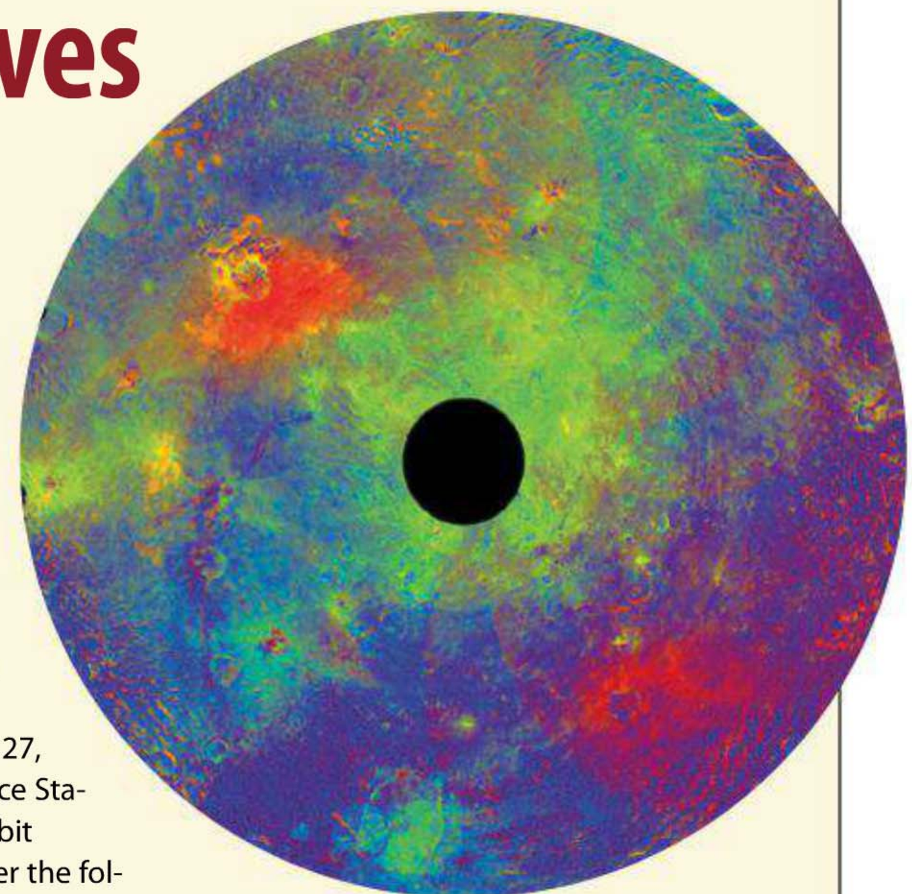
Some 3,800 light-years away, the old star KIC 05807616 (also known as KOI 55) left its red-giant phase millions of years ago. A team of astronomers used NASA's planet-hunting Kepler space telescope to observe it, but they weren't searching for planets. The orbiting observatory simply provided the kind of data they wanted.

After analyzing the data, though, the team discovered two planets roughly 76 percent and 87 percent as big as Earth. Named KOI 55.01 and KOI 55.02, the pair orbits their sun extremely closely — only 0.6 percent and 0.76 percent the Earth-Sun distance, respectively. This means when KIC 05807616 was a red giant, it would likely have swallowed the planets.

"Only planets with masses very much larger than the Earth, like Jupiter or Saturn, could possibly survive," says co-author Elizabeth Green of the University of Arizona in Tucson. In fact, it's possible the planets could account for an unusual loss of mass within the star, giving astronomers new insight into stellar and planetary development.

"This is a snapshot of what our solar system might look like after several billion more years of evolution," says co-author Steve Kawaler of Iowa State University in Ames. "This can help us learn about the future of planetary systems and of our own Sun." — **B. A.**

Dawn moves closer to Vesta

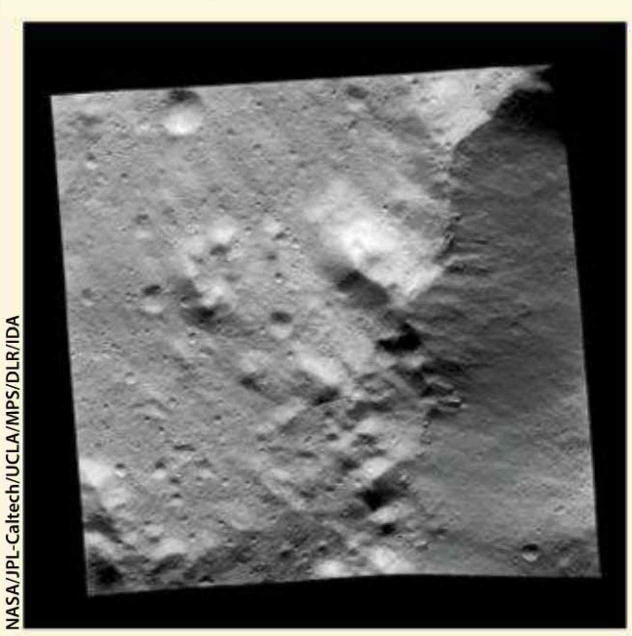


Asteroid composition. **This false-color mosaic of Vesta's southern hemisphere shows different surface materials. Green likely corresponds to the iron-rich mineral pyroxene, but scientists aren't yet sure what red and blue regions show.** NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

Scientists with NASA's Dawn mission had a busy December. They released data showing different rock and mineral types of asteroid Vesta, in addition to the first close-up images of its surface from the spacecraft's low-altitude science orbit.

The craft launched September 27, 2007, from Cape Canaveral Air Force Station in Florida and entered into orbit around Vesta on July 15, 2011. Over the following five months, it captured surface data in mostly visible and infrared radiation. Such observations tell astronomers about the surface materials and also topographic variations like impacts and layered structures.

"The distinct compositional variation and layering that we see at Vesta appear to derive from internal melting of the body shortly after formation, which separated Vesta into crust, mantle, and core," says Dawn's deputy principal investigator Carol Raymond of NASA's Jet Propulsion Laboratory in Pasadena, California. The team announced these findings December 5 at the American Geophysical Union meeting in San Francisco, California.



NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

Battle of ages. **A ridge within the Rheasilvia Basin in Vesta's south polar area shows younger material (dark regions) ejected by an impact on top of older, brighter material. The image, released December 13, spans 12 by 12 miles (20 by 20 kilometers) and was captured from 127 miles (204km) above the surface.**

Just a few days later, on December 12, members of the Dawn mission reported that the craft had successfully spiraled into its close monitoring orbit — averaging about 130 miles (210 kilometers) from the surface. For at least 10 weeks, Dawn's main goals would be to collect data with its gamma-ray and neutron detector (GRaND) and its gravity experiment.

High-energy particles called cosmic rays slam into Vesta's surface, and interactions with atoms create energy and particles; GRaND captures those byproducts and can use them to identify the types of atoms at the surface. Dawn also can map the way mass is distributed within Vesta by analyzing slight shifts in the craft's communications while it's in close proximity to the asteroid.

While in its low-altitude orbit, the craft captures close-up images of the surface that show details as small as 78 feet (25 meters) per pixel. The photographs have revealed textures such as small grooves and outcroppings of dark and bright material.

After Dawn's low-altitude mapping is complete, the craft will maneuver back out to a high-altitude orbit (420 miles [680km] above the surface) until July 2012, which is when it will leave Vesta and make its way to the dwarf planet Ceres. Dawn should arrive at its second target in February 2015. — **L. K.**

One more down The Kepler space telescope, along with a variety of ground scopes, confirmed the existence of Earth-sized but uninhabitable exoplanet Kepler-21b; results will appear in a future edition of *The Astrophysical Journal.*

Astro**confidential** by Karri Ferron

Where is X-ray telescope technology taking us?

Victoria **Kaspi**

Physics professor at McGill University in Quebec, Montreal, Canada

Technophilic Magazine

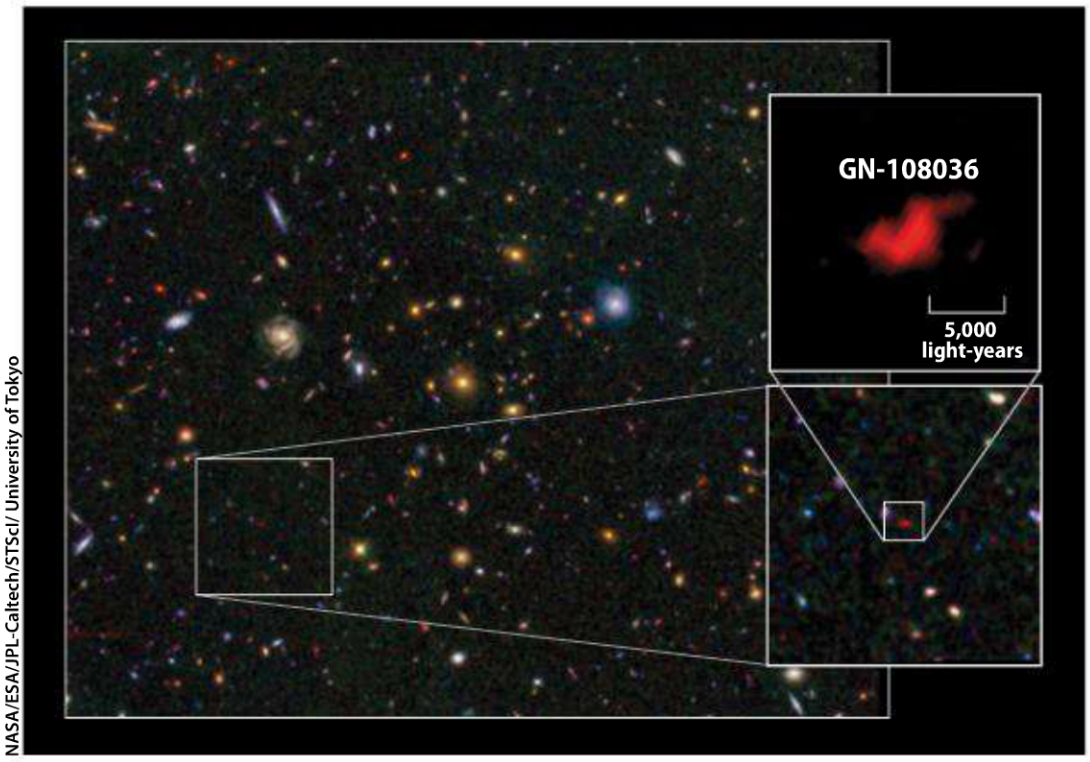
In March 2012, NASA is scheduled to launch the Nuclear Spectroscopic Telescope Array (NuSTAR), the first-ever focusing hard X-ray space telescope.

X-rays, particularly those with high energies (above 10 kiloelectron volts), which scientists call "hard," prefer to travel though material unimpeded. For this reason, previous hard X-ray telescopes struggled to determine the direction on the sky from whence a hard X-ray arrives, yielding blurry images with typical angular resolutions of many arcminutes.

NuSTAR, by contrast, uses multilayer coatings on specially shaped glass mirrors to, for the first time, focus X-rays in the 8–80 keV energy range onto detectors. This will result in high-quality imagery of the X-ray universe.

NuSTAR will launch via a Pegasus rocket from beneath the belly of a specially designed airplane. It will then deploy from a 2-meter length required to fit in the rocket to its 10-meter length. NuSTAR will next use laser metrology to determine the telescope/detector alignment. In this way, the space telescope will be able to pinpoint stars and other point sources to within a few arcseconds — vastly superior to previous hard X-ray telescopes.

As coordinator for galactic science with NuSTAR, I help our science team come up with an observing program that optimizes NuSTAR's capabilities and tackles some of the most interesting problems in high-energy astrophysics today. These include determining the origin of X-ray flares seen from the direction of the Milky Way's central supermassive black hole; resolving the shapes of pulsar wind nebulae and supernova remnants at hard X-ray energies to test models of their evolution; and elucidating the origin of magnetars' and some pulsars' unexpected brightening at X-ray energies above 10 keV. An exciting extragalactic science program is also planned, including studies of the evolution of supermassive black holes.



NASA/ESA/JPL-Caltech/STScI/ University of Tokyo

Sun maker. One of the farthest galaxies found yet was vigorously forming stars. GN-108036, located 12.9 billion light-years away, created stars some 30 times faster than the Milky Way does. The Hubble Space Telescope captured these images of the galaxy.

Odd galaxy from an early cosmic era

The search for distant objects has bagged another one, but this galaxy is the brightest galaxy yet found so far away. At 12.9 billion light-years distant, GN-108036 was forming stars at a rate of about 100 per year; the Milky Way makes about 30 times fewer suns each year. The finding appeared online December 15 in *The Astrophysical Journal*.

The team, led by Masami Ouchi at the University of Tokyo in Japan, found the galaxy in a sky survey performed by the Subaru Telescope atop Mauna Kea in Hawaii. To determine the object's distance and composition, the astronomers used the nearby Keck Observatory and the orbiting Hubble Space Telescope.

They found that GN-108036 existed just 750 million years after the Big Bang, and that it was brighter than expected. "The galaxy's intense brightness in the intrinsic ultraviolet indicates that it contained many young, massive stars," says team member Mark Dickinson of the National Optical Astronomy Observatory in Tucson, Arizona. "In addition, we found that the galaxy [had] a diameter of about 5,000 light-years, only 5 percent as large as that of our own Milky Way Galaxy." — **L. K.**

FAST FACTS

1.3 MILLION

The spin speed, in miles per hour (600 kilometers per second), of the fastest-rotating massive star, according to a December 10 paper in *The Astrophysical Journal Letters*.

10,000

The number of science papers based on Hubble Space Telescope data as of December 6, according to NASA.

T. A. Rector (University of Alaska, Anchorage)/H. Schweiker and S. Pakzad/NOAO/AURA/NSF

Super-duper supernova. Astronomers spotted SN 2011fe, the bright blue star near upper right, so early in its stellar explosion that observations revealed much about what kinds of stars can become supernovae and what the blasts are like.

August supernova offers cosmic clues

When he spotted an extremely young type Ia supernova this past August, Peter Nugent of the University of California, Berkeley, called it "an instant cosmic classic." Then, in a December 15 paper in *Nature*, lead author Nugent and the rest of the Palomar Transit Factory (PTF) team published the first analysis of the object's data, confirming some theoretical assumptions about these stellar blasts, but also finding surprises.

Named SN 2011fe, the explosion took place in spiral galaxy M101, 21 million light-years away. "We caught the supernova just 11 hours after it exploded," says Nugent, "so soon that we were later able to calculate the actual moment of the explosion to within 20 minutes." Astronomers have long theorized what kind of star and stellar system could produce such a blast, but SN 2011fe's light signature provided the first evidence for these models.

"Sure enough, it could only have been a white dwarf," says Nugent. "The early-time light curve also constrained the radius of the binary system … so we got rid of a whole bunch of models." The current scenario determines the pre-supernova star was part of a double star system (as are about half of all stars), with its companion likely a main sequence star like our Sun.

The astronomers also learned a great deal about the mechanics of type Ia supernovae, including the "tremendous amount of mixing" of stellar materials throughout the explosion. "This is not something any of us would have expected," says Nugent.

"It is rare that you have eureka moments in science, but it happened four times on this supernova," says co-author Andy Howell of the University of California, Santa Barbara. "The super-early discovery; the crazy first spectrum; when we figured out it had to be a white dwarf; and then, the Holy Grail, when we figured out details of the second star." — **B. A.**

Small singularity NASA announced December 15 that it had found what could be the smallest-known black hole, likely less than three times as massive as our Sun.

Earth-sized worlds discovered around Sun-like star

Since May 2009, NASA's Kepler spacecraft has searched for planets around more than 150,000 stars by looking for the telltale dimming that occurs when a world passes in front of its parent sun. It has uncovered more then 2,000 planet candidates, but mission scientists announced online December 20 in *Nature* one of their biggest achievements to date: With the help of ground-based telescopes, the Spitzer Space Telescope, and a computer program to rule out other astronomical phenomena, Kepler has found the first two Earth-sized planets around a Sun-like star.

Kepler-20e and Kepler-20f are some of the smallest exoplanets discovered to date. At 6,900 miles (11,100 kilometers) across, Kepler-20e is slightly smaller than Venus. Kepler-20f is 8,200 miles (13,200km) in diameter, or 3 percent larger than Earth.

Although both probably have rocky compositions, they are not suitable for life. Kepler-20e orbits its parent star every 6.1 days at a distance of only 4.7 million miles (7.6 million km), so its surface temperature is a scorching 1,400° Fahrenheit (760° Celsius). Kepler-20f orbits in 19.6 days from 10.3 million miles (16.6 million km) away, and the planet reaches temperatures comparable to those on Mercury (800° F [427° C]).

The Kepler 20 system also includes three other planets larger than Earth but smaller than Neptune, with the worlds organized in alternating size (big, little, big, little, big). And these small planets have scientists excited about the coming months. "In the cosmic game of hide and seek, finding planets with just the right size and just the right temperature seems only a matter of time," says Natalie Batalha, Kepler deputy science team leader at San Jose State University in California. "We are on the edge of our seats knowing that Kepler's most anticipated discoveries are still to come." — **KARRI FERRON**

Earth-sized exoplanets. NASA's Kepler mission has confirmed the first two Earth-sized planets around a Sun-like star. Kepler-20e measures 0.87 times Earth's diameter, while Kepler-20f is 1.03 Earths across. NASA/AMES/JPL-Caltech

BRIEFCASE

Particle hunt

Members of two experiments at the European Organization for Nuclear Research (CERN) announced December 13 that they had constrained the energy range in which the mysterious Higgs boson could be hiding. Scientists haven't yet discovered the particle, but according to physics theories, it is the missing piece of physicists' standard model. In short, the Higgs gives other particles their masses. — L. K.

The Sun erodes the Moon

Occasionally, the Sun emits a huge gust of hot plasma called a coronal mass ejection (CME). A CME can strip 100 to 200 tons of material from the Moon's surface as the gust passes the satellite, according to a new NASA computer simulation presented December 5 at the American Geophysical Union meeting in San Francisco, California. The team intends to compare its data to future CME observations. — L. K.

Monster black holes measured

On December 5, a team of astronomers led by Nicholas McConnell of the University of California, Berkeley, announced that it has found the two most massive black holes yet. These monsters — each clocking in at about 10 billion times the mass of our Sun — lie in huge elliptical galaxies at the centers of galaxy clusters. One belongs to NGC 3842 and the other to NGC 4889. — L. K.

25 years ago in *Astronomy*

April 1987

In the April 1987 issue, science writer Lys Ann Shore extolled the virtues of a prodigious orbiting telescope in "IUE: Nine Years of Astronomy." Long before the Hubble Space Telescope's reign, the International Ultraviolet Explorer (IUE) surpassed nearly all expectations. In its first eight years, Shore wrote, IUE data produced 1,136 scientific papers that "announced, explained, refined, and extended major discoveries in many areas of astronomy, from solar system to stellar to extragalactic research."

In all, IUE spent 18 years collecting space data before budget concerns forced its shutdown in 1996. The telescope was still in good condition at the time, though, and it continues to orbit Earth. Not bad for a mission designed to last only three years.

10 years ago in *Astronomy*

April 2002

The April 2002 issue featured a special package of articles about cosmic inflation, a theory tweaking previous conceptions of the Big Bang that *Astronomy*'s editors called "a panacea for a long list of chronic cosmological concerns."

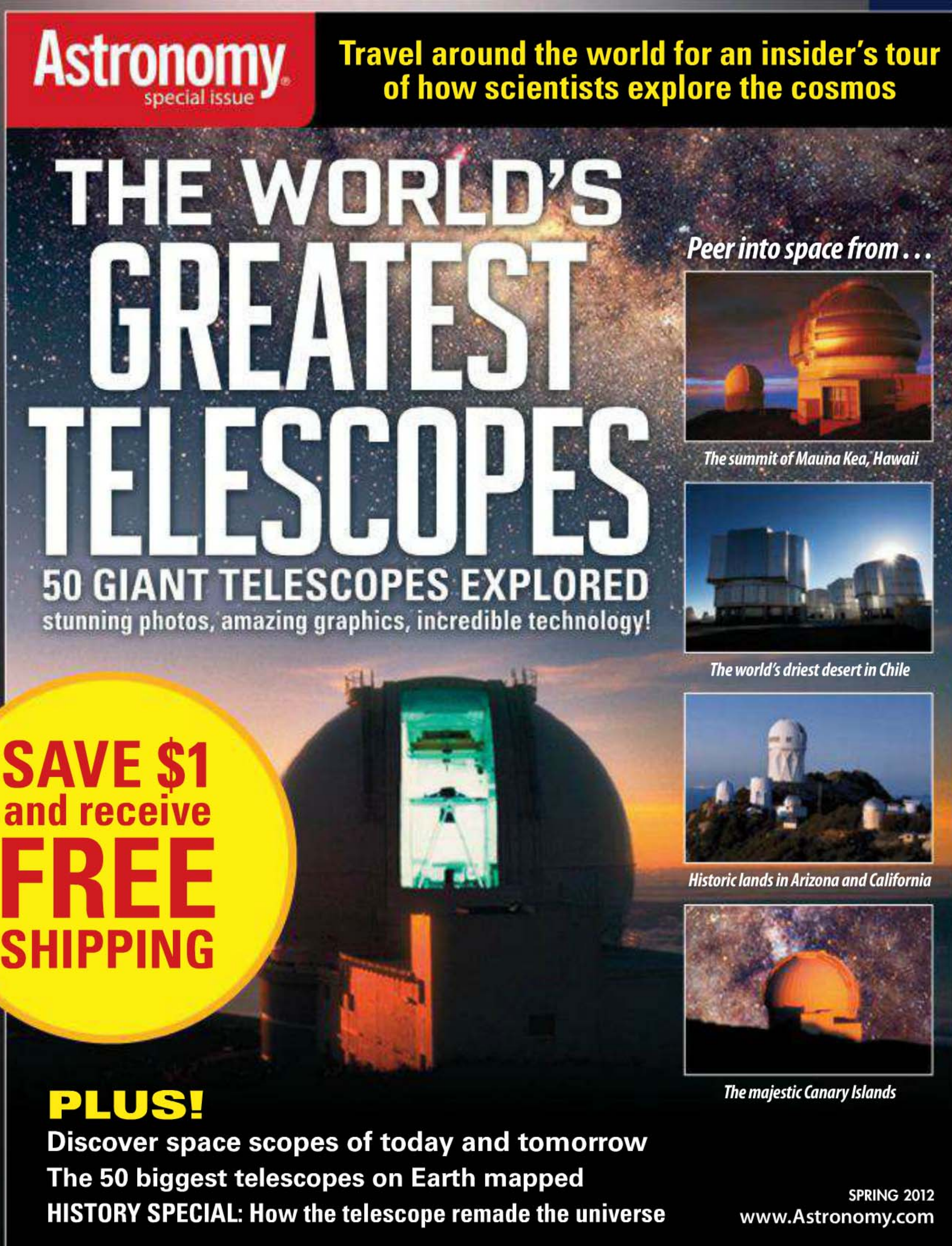
Frequent contributor Steve Nadis began the parade with his story, "Cosmic Inflation Comes of Age." In it, he summarized the need for some kind of method to fix the "gaping holes" in Big Bang theory, as well as explaining how cosmic inflation worked and detailing some of its consequences.

Nadis also provided a series of "Inflation Minifeatures," where he explored such tangential ideas as eternal universes, string theory, dark energy, alternative forms of inflation, and the physicists' search for a "Theory of Everything."

Finally, *Astronomy* posted on Astronomy.com more stories about the people who developed inflation, as well as their experiences doing so. — **B. A.**

NEW
special issue

GET A CLEAR VIEW



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Gravitational sinkholes

HOW WE KNOW BLACK HOLES EXIST

Despite their invisibility, black holes noticeably modify their environments by producing high-speed jets and abnormally quick stellar movements. **by Liz Kruesi**

In the late 18th century, two scientists (John Michell and Pierre-Simon Laplace) separately theorized that a star could be so massive that not even light could escape its surface. But nothing more was made of these "dark stars" until the 20th century, when Albert Einstein published his general theory of relativity. His idea turned the notion of gravity on its head: It isn't really a push/pull force, but instead describes how mass affects the fabric of space-time. And general relativity made possible the reality of those dark stars.

In 1916, just one year after Einstein published his theory, physicist Karl Schwarzschild calculated general relativity's gravitational equations in an extreme case (when an object has a mass near infinity) and found that the fabric of space-time would fold in on itself, creating a "singularity" — a region with zero volume and infinite density. Such a point would not allow matter or even light to escape. Today's term for this object — a black hole — came 50 years later, around the same time researchers began discovering hints of them.

Now, after 40 years of research, scientists are positive these extremely dense bodies exist, and that there are two different types. Astronomers categorize black holes as either stellar mass (which range from three to tens of times our Sun's mass and mark the end state of a massive star) or supermassive (which are millions to billions of times our star's mass and sit at the centers of galaxies).

Liz Kruesi *is an associate editor of* Astronomy *magazine. She has no interest in seeing a black hole up close.*

The smaller variety

Over the years, different methods have convinced scientists that both types of black holes exist. One of the most successful techniques astronomers have used to find both stellar and supermassive black holes is monitoring the movements of stars near suspected black holes. They use the visible companion in a binary system as a tracer.

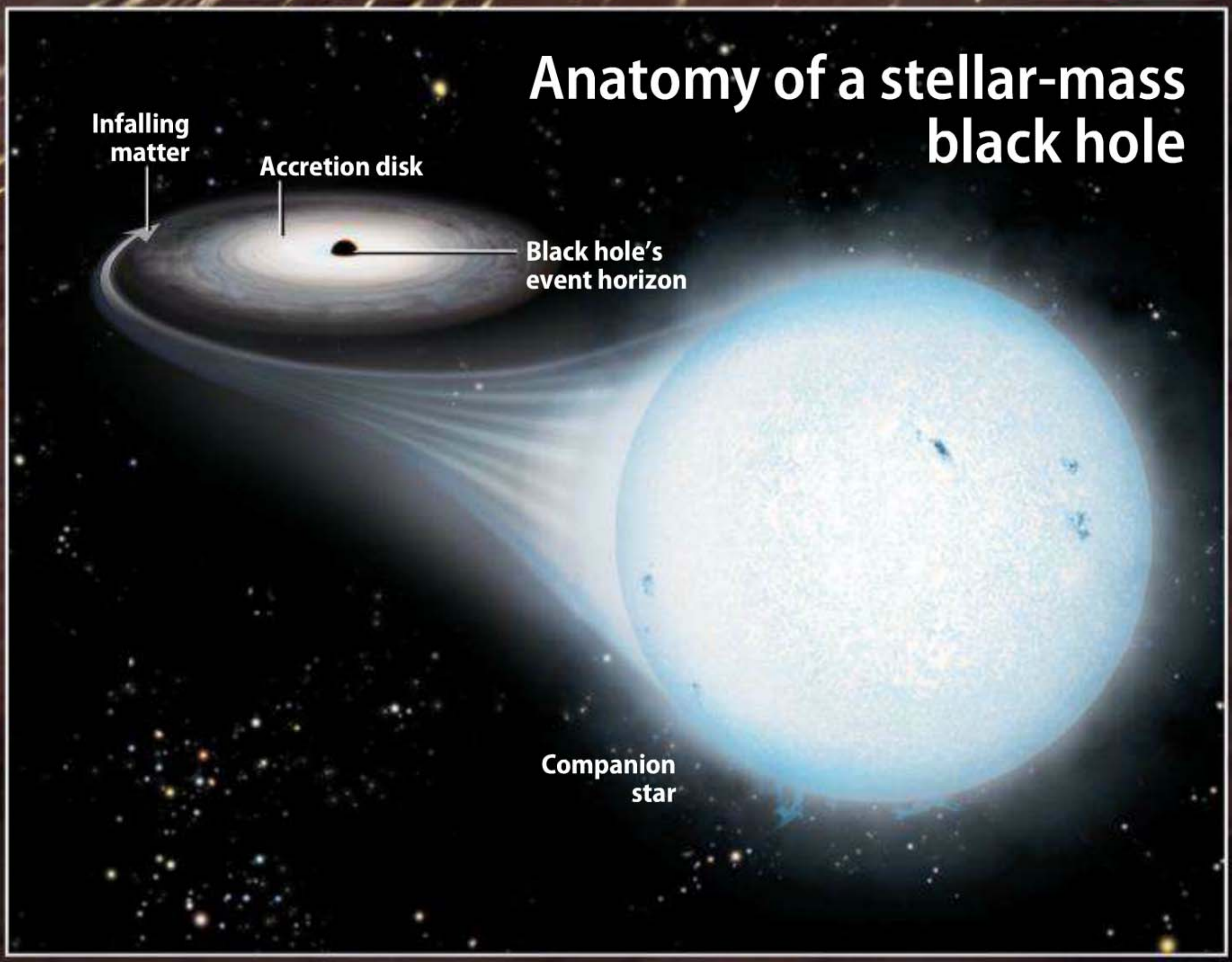
This method arose in the late 1960s when X-ray detectors aboard satellites spotted sources of X-rays in our galaxy. Many of these changed brightness over fractions of a second, so astronomers called them "X-ray transients." Scientists soon realized that some of these objects were binary systems.

In X-ray binaries, if the two bodies are close enough, the compact object pulls hot gas from the star. The stellar material heats up to millions of degrees due to friction and emits X-rays. The unseen compact companion could be a neutron star or a black hole; both are small enough to appear "invisible" until gas falls onto them, which then heats up and produces a bright X-ray source. To distinguish between the two

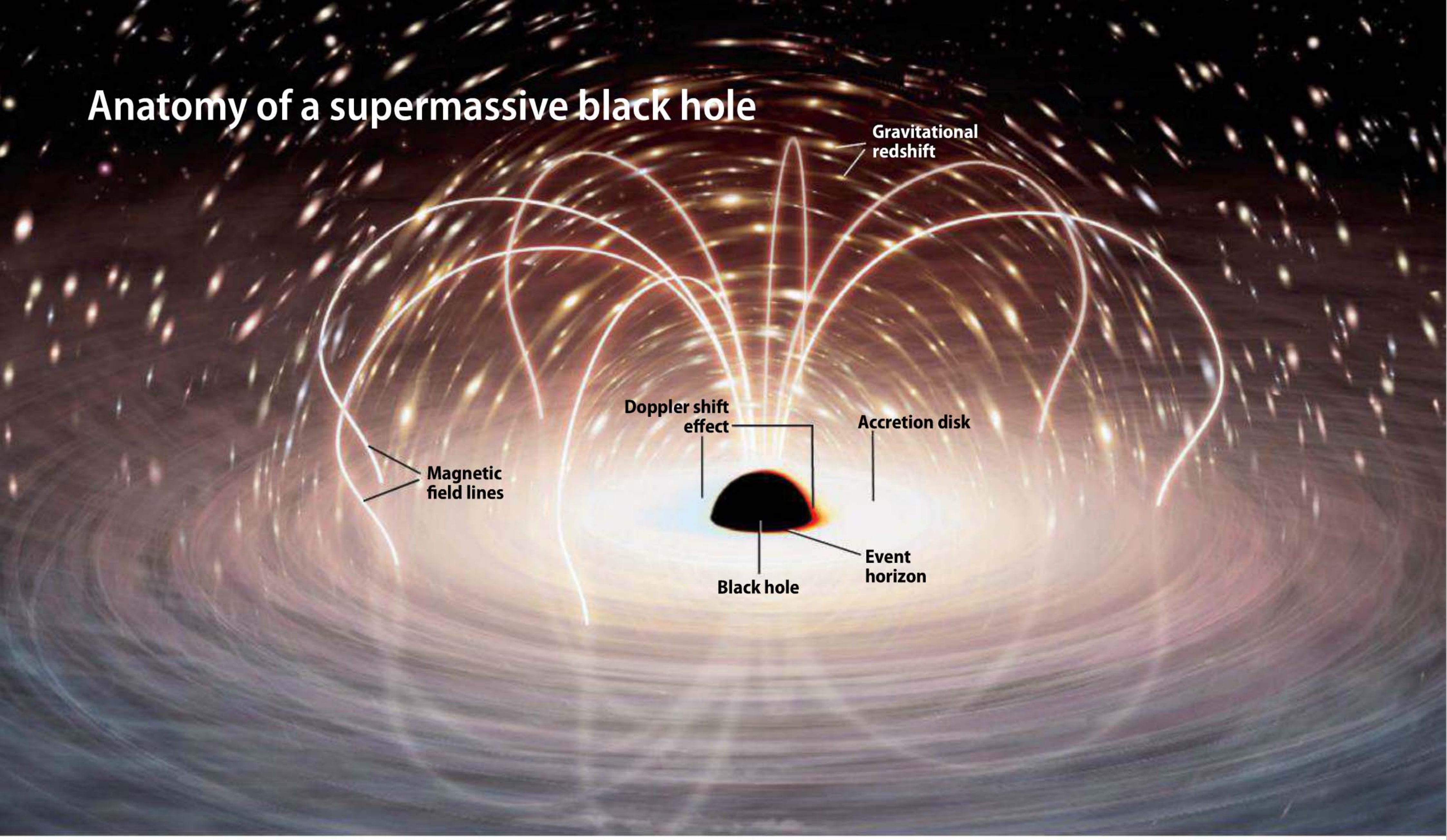
A black hole warps space-time to the extreme, creating a point where the cosmic fabric folds in on itself. Any mass or light that comes within a certain distance — called the event horizon — will fall in and never escape. *Astronomy*: Roen Kelly

possibilities, scientists need the invisible object's mass, which they can determine using basic physics laws.

Astronomers collect data through the visible star's spectral emission, which tells them about the star's composition and movement. As the star moves away from Earth in its orbit around its invisible companion, its emission shifts slightly toward the red end of the electromagnetic spectrum; as it speeds toward our planet, its emission shifts to the blue end. From the amount the spectrum shifts, astronomers can determine how fast the visible star is moving and how long it takes to complete one orbit. Then, using the same law of physics that dictates how the planets orbit the Sun, they can calculate the mass of the unseen companion.



A stellar-mass black hole is the last stage of evolution of a star that once was at least 30 times our Sun's mass. This black hole holds between about three and tens of solar masses crammed into an area about the size of a large city. *Astronomy*: Roen Kelly



A supermassive black hole contains millions to billions of solar masses in an area comparable to the solar system. Astronomers are nearly certain of a handful of these objects, but they think every galaxy may harbor one at its center. *Astronomy*: Roen Kelly

If it's less than about three times the Sun's mass (called a solar mass), it's a neutron star. If the companion holds more than three solar masses, it's likely a black hole. From such measurements, astronomers have identified about 20 stellar-mass black hole candidates.

Cygnus X-1 was one of the first X-ray binaries studied. In 1971, astronomers noticed that a hot blue giant star, HDE 226868, sat at the same location in the sky as an X-ray source. This star moved at about 43 miles per second (70 kilometers per second) around an unseen companion, completing an orbit in 5.6 days.

After gathering more data, the scientists calculated that the companion was at least four solar masses. Today, astronomers know HDE 226868 tips the scales at about 19 solar masses and its unseen companion contains some 15 solar masses. They are also convinced that the invisible object is a black hole that's the stellar remnant of a once extremely massive star.

Now you see it, now you don't

Scientists have gained other clues from X-ray binaries. In 2006, astronomers announced a study monitoring radiation linked to about three dozen X-ray binary systems. Out of those, 13 contained expected neutron stars, 18 comprised suspected black holes, and a handful were unclassified sources. The team, led by Ronald Remillard of the Massachusetts Institute of Technology (MIT) in Cambridge, analyzed nine years of data from the Rossi X-ray Timing Explorer (RXTE) and found 135 X-ray flashes that corresponded to the neutron star candidates, whereas the signal died out when observing the black hole candidates. This is exactly what scientists would expect if accreted material moved toward and past a black hole's boundary of no return — its "event horizon." The team watched as energy disappeared.

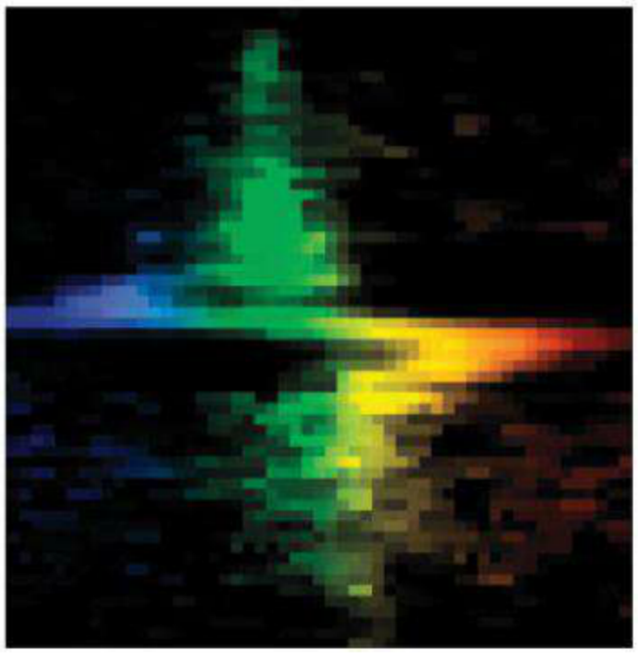
"X-ray flashes [indicate the] fusion of material that builds up on the surface of a neutron star," says Eliot Quataert of the University of California, Berkeley. "Black holes don't have such a surface," and therefore no flashes.

The lack of X-ray flashes is indirect proof that an event horizon exists, and if one exists, so does a black hole. "To prove that it's an event horizon, you have to have missing energy," says Karl Gebhardt of the University of Texas at Austin. "It has to be there and then not [be] there." Astronomers also have seen similar cases of "missing" energy associated with supermassive black hole candidates.

> **THE STRONGEST EVIDENCE THAT BLACK HOLES EXIST LIES AT THE CENTER OF OUR GALAXY.**

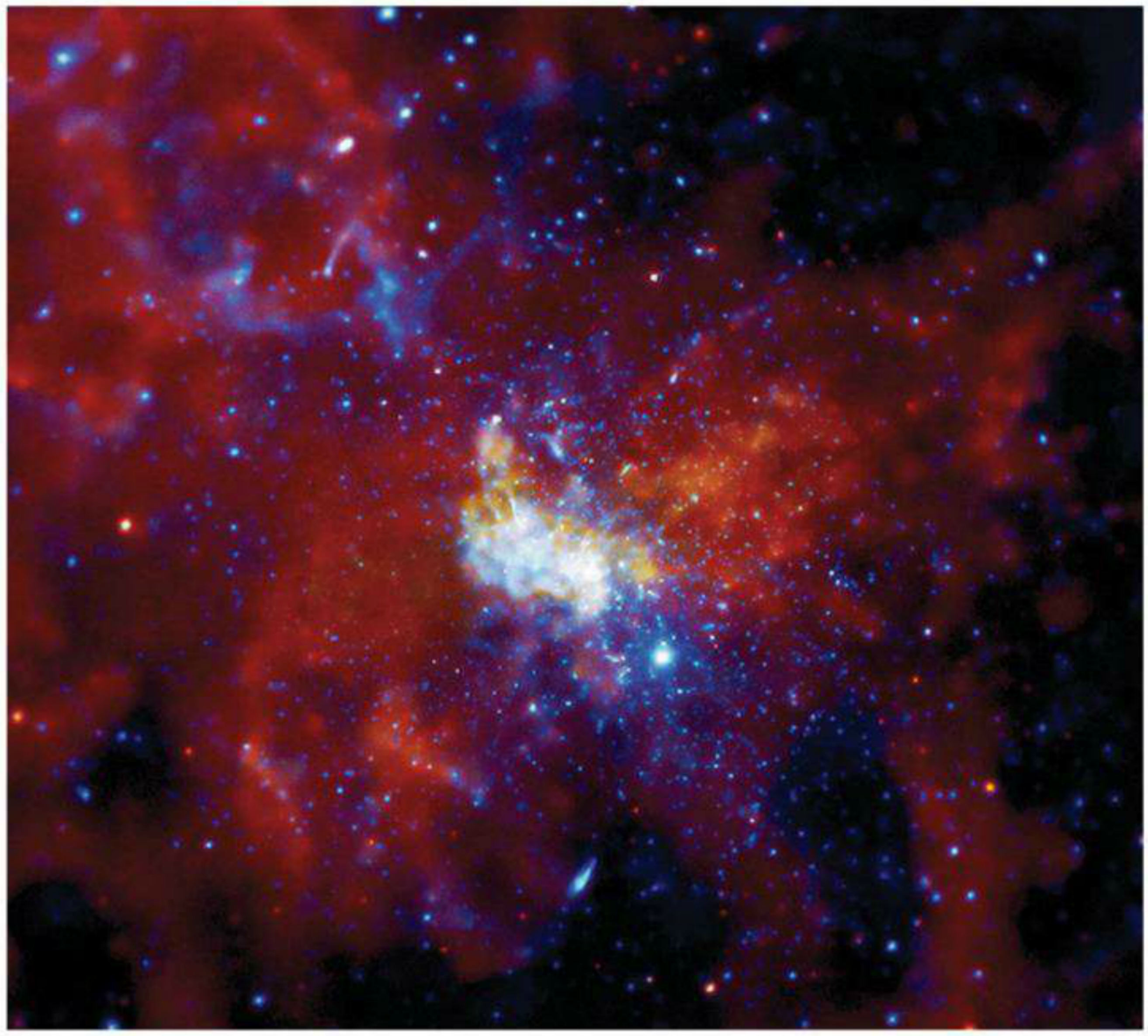
The larger variety

The strongest evidence that black holes exist lies at the center of our galaxy. Two groups of astronomers — one led by Reinhard Genzel of the Max Planck Institute for Extraterrestrial Physics in Garching, Germany, and the other led by Andrea Ghez of the University of California, Los Angeles — have monitored the movements of dozens of stars at the Milky Way's center for 15 years. "The



Gary Bower/Richard Green (NOAO)/STIS Instrument Definition Team/NASA

Scientists can figure out how quickly gas, or even a star, is moving around a black hole by looking at its spectrum. As the gas, in the case shown here, speeds toward Earth in its orbit, it appears bluer; as it moves away from Earth, it shifts to red. Scientists used this observation to determine that the gas within 26 light-years of M84's core whips around at 220 miles per second (360 kilometers per second). For the gas to move so quickly, some 300 million solar masses would need to lie within that distance.



The Milky Way Galaxy's core holds the most-convincing black hole candidate. Astronomers have studied the object, called Sagittarius A*, using radio, infrared, and X-ray telescopes and have ruled out other possible entities. NASA/CXC/MIT/F. K. Baganoff, et al.

orbits of the stars are consistent with ellipses," says Quataert. "What that tells you is that the gravity that makes the stars move the way they move is consistent with a single object at the center, just like [how] in our solar system the Sun is at the center."

From measurements of those stars' orbits, astronomers determined the mass of the unseen object inside their orbits; the center of the Milky Way Galaxy contains some 4 million solar masses within a region about the size of our solar system. The size and the mass then give the object's density. "And once you have the density, that's what really tells you if it's a black hole or other strange models," says Gebhardt.

Astronomers used to propose that the galaxy's center harbors clumps of neutron stars or white dwarfs, but both Genzel's and Ghez's teams have "been able to probe close enough to the black hole that, effectively, all other models that can try to explain that amount of mass have been ruled out," says Gebhardt.

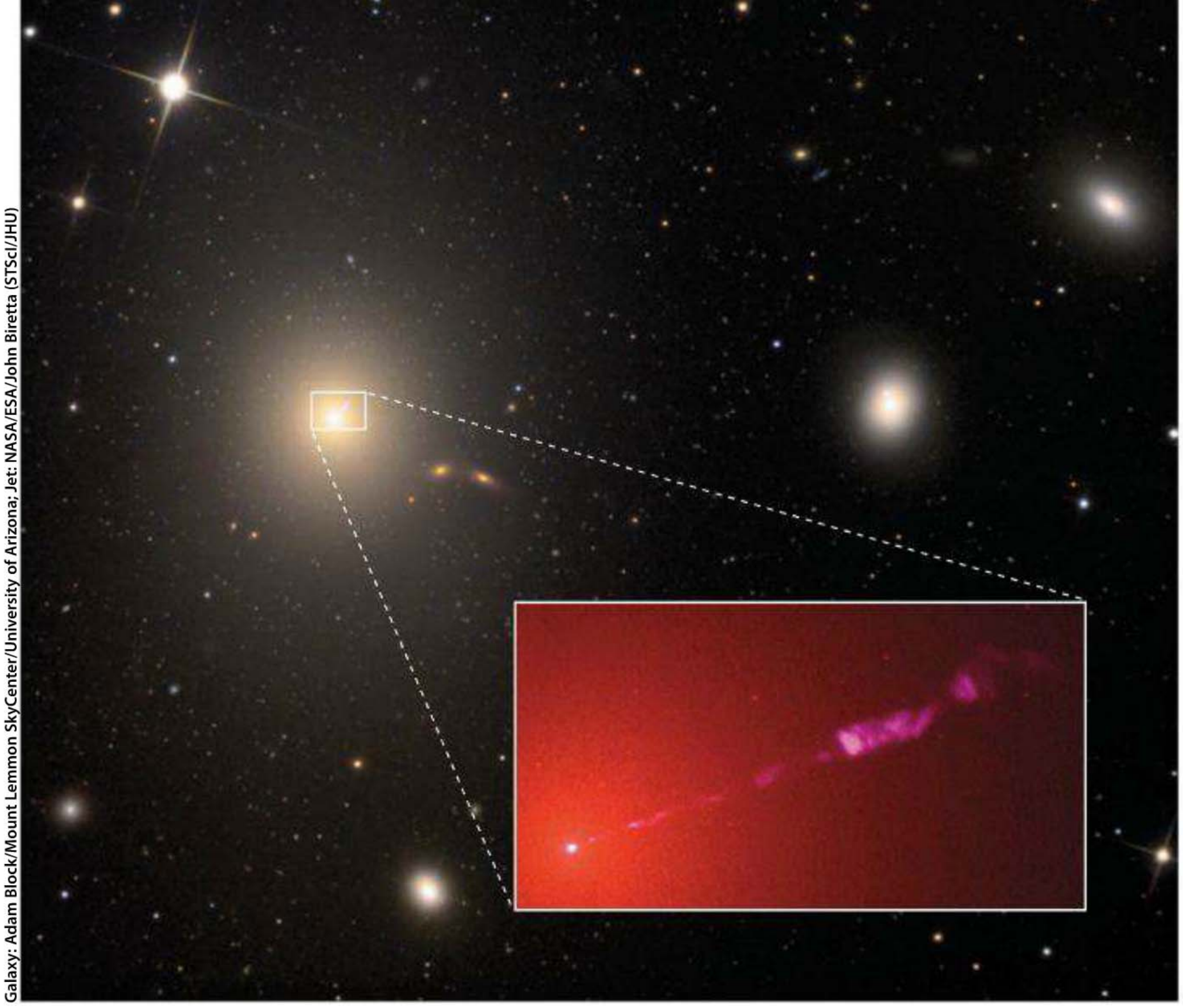
Identifying the object at our galaxy's center, which astronomers call Sagittarius A*, didn't just involve the motions of those few dozen stars — although they do provide the strongest evidence. In 2003, Genzel's team observed a brief infrared signal from the same location as the theorized supermassive black hole. The emission brightened, faded, and disappeared 30 minutes later. The team pinpointed the radiation's location to just a few thousandths of an arcsecond (corresponding to a distance of a few light-hours) from the black hole, and they think it results from material falling past the event horizon. The material heats up and emits infrared radiation as it approaches the massive object, but the signal disappears as the black hole's grip overtakes the gas, pulling it beyond the point of no return.

Not just the Milky Way

In addition to the Milky Way, scientists know of three other candidate galaxies that almost certainly harbor supermassive black holes. One is the mammoth M87, part of the Virgo cluster. Although the galaxy is about 50 million light-years from Earth, astronomers can monitor the movements of individual stars. They also track the motion of gas near the galaxy's center by observing particular spectral lines.

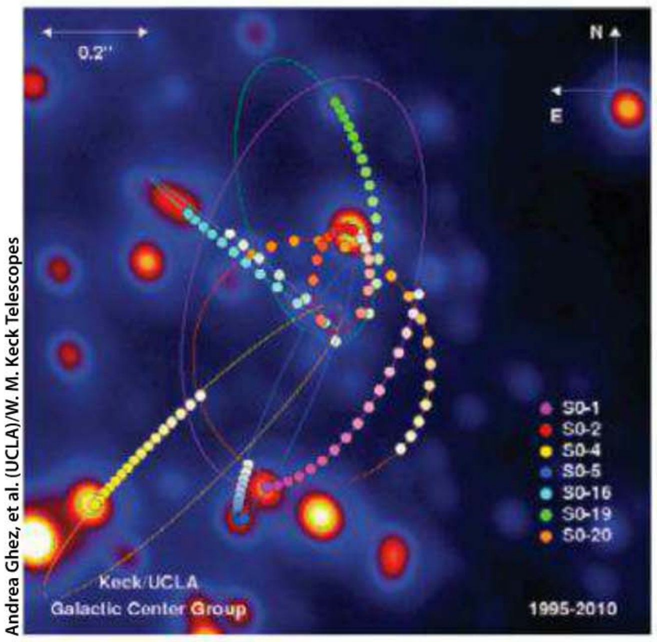
Gas and stars in the disk that surrounds a black hole revolve quickly. Just like in the stellar-mass candidates, astronomers can observe the redshift and blueshift of the material's spectral lines. The amount of shift corresponds to how fast the stuff is moving. Using this velocity and the amount of time stars take to complete a full orbit around the center of M87, Gebhardt and colleagues determined that the object at the center of the accretion disk holds some 6.6 billion times our Sun's mass — that's more than 1,000 times that of the Milky Way's central black hole. M87's central supermassive black hole holds that huge mass within a region about three times the solar system's width. (The same team also measured the masses at the centers of NGC 4889 and NGC 3842: Each holds some 10 billion solar masses in a space a few times the solar system's size.)

Astronomers used a different method in the late 1990s and early 2000s to calculate the mass of the suspected black hole at the center of the galaxy M106 (NGC 4258). They found a handful of water masers — objects that amplify light of a specific frequency, and thus are easy to track — within the inner 3 light-years of the galaxy. By observing the motions of those masers with the Very Long Baseline Array of radio telescopes scattered across the globe, the team determined the speed at which the objects were moving. It then calculated that some 30 million solar masses sit within that



Galaxy: Adam Block/Mount Lemmon SkyCenter/University of Arizona; Jet: NASA/ESA/John Biretta (STScI/JHU)

Elliptical galaxy M87 in Virgo almost certainly holds a central supermassive black hole containing 6.6 billion solar masses. The object also shoots out high-speed jets of matter and radiation (inset).



Andrea Ghez, et al. (UCLA)/W. M. Keck Telescopes

Astronomers tracked the motions of stars within 16 billion miles of the Milky Way's core and found that they're orbiting as though there's a single massive object at the center of our galaxy. Using basic physics laws, they determined a supermassive black hole about 4 million solar masses lies within a solar-system-sized region.

region, which is smaller than the distance between the Sun and the next nearest star.

M106, along with the Milky Way, M31, and M87, contains a central object with such a high density that astronomers have ruled out any other explanation. These four galaxies almost certainly harbor supermassive black holes at their cores.

Marking the spot

Ever since the 1960s, when astronomers began discovering extremely luminous distant galaxies called quasars, they've wondered what creates them. The leading theory is that as a supermassive black hole's gravity distorts space-time nearby, it also twists its magnetic field. So when material spirals into the black hole, magnetic field lines funnel radiation and matter into regions perpendicular to the disk. This creates high-speed jets.

For decades, scientists have found radio sources at the same sky positions as possible black holes with matter moving at nearly the speed of light. But recent findings helped connect such radiation to black holes.

In one study using the Swift satellite, which looks for high-energy emissions, astronomers spotted X-ray flares in addition to gamma and radio emission at the same position. They found that this material was moving toward Earth at more than 90 percent the speed of light. "The radio emission occurs when the outgoing jet slams into the interstellar environment," explains Ashley Zauderer of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, leader of the radio study. "By contrast, the X-rays arise much closer to the black hole, likely near the base of the jet."

The researchers are convinced that they saw a star come too close to a black hole's event horizon. Gravity stretched it, funneling the gas into an accretion disk; the friction in the disk caused the star to emit X-rays. Then the material moved past the event horizon and the signal died out. In a couple years, scientists expect to be able to image the jet in radio wavelengths, which would add another level of confidence to the theory.

Using the RXTE, another team watched a similar situation. It spotted a faint oscillating signal from the binary system H1743-322 (which contains an unseen companion) that seemed to speed up; they think this was a blob of material orbiting close to the black hole. The signal then disappeared, and two days later the group saw a "bullet" of gas shoot out from the disk. The following day, they saw another on the opposite side.

Scientists also have detected high-speed jets shooting from the center of M87, in addition to M81, NGC 2273, and a handful of other galaxies, suggesting they all harbor supermassive black holes.

THE EVENT HORIZON TELESCOPE WILL TRY TO DIRECTLY OBSERVE A BLACK HOLE'S BOUNDARY OF NO RETURN.

Looking for the absolute

Although scientists have found convincing evidence that black holes exist, "the defining property of a black hole is the existence of the event horizon — this point of no return," says Gebhardt. "The proof of that is very elusive." The sighting of an event horizon would be solid evidence, but scientists haven't found one yet. In the next few years, they just might.

Telescope arrays are in the works that will have the resolution to image a region where no light emanates. "If the estimated event horizon of a black hole is large enough, you could see its optical absorption effects and you could actually see a hole if there was background material," says Gebhardt. The two best candidates for such an observation are the supermassive black holes at the centers of M87 and our Milky Way. These two objects would span a large enough area to take an image and see structure.

According to general relativity, a black hole's immense gravity can warp space-time around it so much that light could not escape its clutches. "One prediction is that you'd literally see the absence of emission from some region very close to the event horizon," explains Quataert. This extreme gravitational lensing creates what's called a black hole's "shadow," and it's a bit farther out than the event horizon.

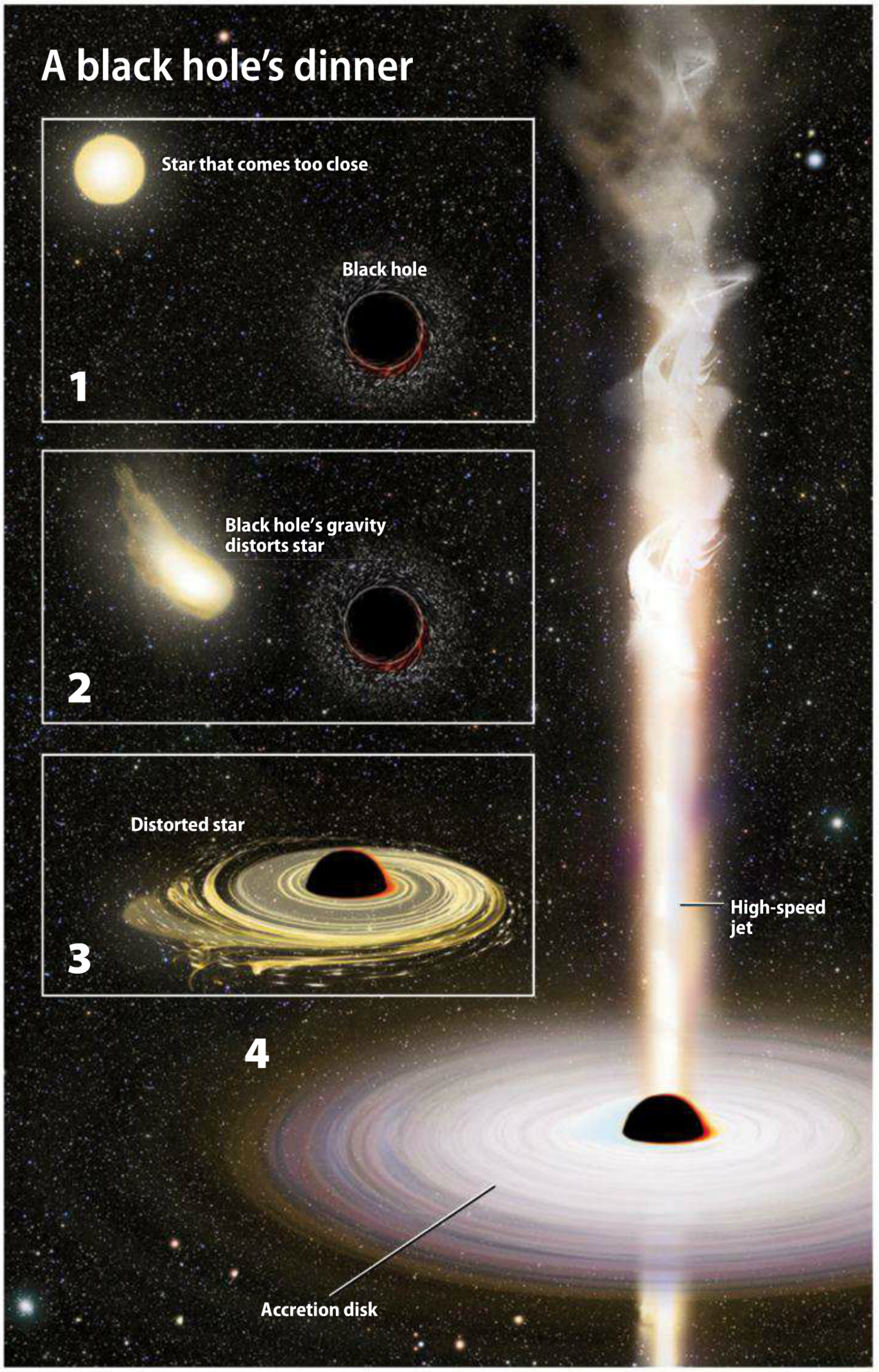
Any object with mass warps space-time, and therefore light passing near it would bend slightly. When you're far away, light deflects only a tiny amount. "But as you move closer to the black hole, that effect gets bigger," says Quataert. "And at some point, it's so dramatic that light rays can wrap all the way around the black hole and start looping around. And that happens somewhere outside the event horizon, at a well-defined place" predicted by general relativity. A direct observation of this shadow, such as a "dark spot" in background material, would prove the existence of black holes.

What the future holds

The key to seeing a shadow, event horizon, or material spiraling into a black hole is using a detector with high resolution. One group, led by Frank Eisenhauer of the Max Planck Institute, plans to use the Very Large Telescope array in Chile with an instrument it's creating to precisely measure the position of stars near a suspected black hole. This apparatus, called GRAVITY, should be able to measure the position of a light source with a resolution of 10 microarcseconds starting in 2014. "In the case of a flare — when the black hole lights up — the brightness is likely dominated by a single 'bright blob' orbiting the black hole at a radius of about three times the event horizon," explains Eisenhauer. "Since the orbiting blob is dominating the brightness in the black hole region, GRAVITY will measure the motion of this 'blob' on its in-spiral onto the black hole."

The next generation of X-ray telescopes might also probe material closer to the event horizon and even gas falling past that boundary. But these projects may have to wait until the 2020s.

A nearer-term instrument, called the Event Horizon Telescope, will try to directly observe a black hole's boundary of no return. Headquartered at MIT, the project will combine radio telescopes across the globe to form an Earth-wide instrument.

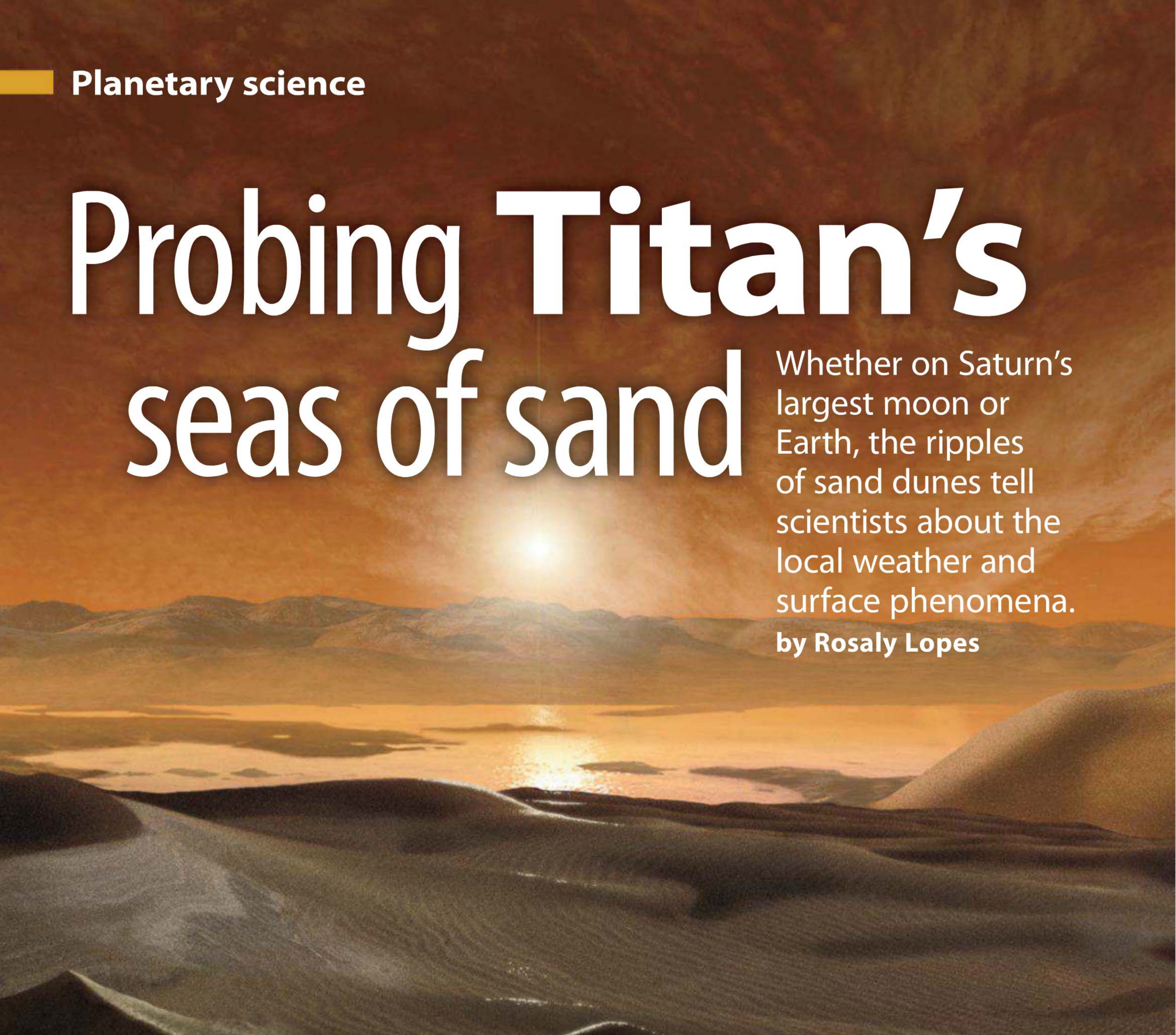


If a star comes too close to a black hole's gravity, some of its gas will be pulled into a disk surrounding the black hole. This material heats up due to friction and radiates X-rays. As the gas loses energy, it falls past the black hole's event horizon. Some material might escape through funnels perpendicular to the disk. Astronomers have observed both the X-ray and radio emissions related to such an event.

Astronomers think it will be possible to image M87's supermassive black hole's event horizon within the next decade.

So, perhaps a century after Schwarzschild first calculated how the fabric of space-time would warp due to an object with nearly infinite density, astronomers might directly observe the telltale sign of the gravitational effects of the most realistic case known. But for now, the evidence they've compiled over the past five decades makes it certain that black holes exist. As Quataert says, "At this point, it's beyond a reasonable doubt."

View how stars orbit Sagittarius A* at www.Astronomy.com/toc.



Probing Titan's seas of sand

Whether on Saturn's largest moon or Earth, the ripples of sand dunes tell scientists about the local weather and surface phenomena.

by Rosaly Lopes

Titan has long been an object of wonder in the solar system. First spotted in 1655 by Christiaan Huygens, Saturn's largest moon hid its surface behind a shroud of haze until the Cassini-Huygens mission arrived there three and a half centuries later.

When the Cassini orbiter began studying the moon in 2004 and the Huygens probe landed on it in 2005, we finally began to get a good picture of Titan's surface. Far from our Moon's old, cratered landscape, Titan proved to be a complex world, with interaction between its surface and atmosphere forming noticeable features — from seas of liquid methane near both poles to seas of sand near the equator. Fantastically, the more we learned, the more recognizable it became.

Almost familiar

Despite many differences, Titan has much in common with Earth. The moon's atmosphere, like ours, is mostly nitrogen, and its surface pressure is 1.5 bar (compared to 1 bar on Earth at sea level), but the air's density at the surface is four times Earth's. Both have precipitation and liquid lakes, but while Earth has a hydrological cycle based on water, methane drives Titan's equivalent cycle. Surface temperatures on the moon are so cold, about –288° Fahrenheit (–178° Celsius), that methane can exist as a liquid, solid, or gas.

Titan's surface boasts extensive river channels carved into icy bedrock, heavily eroded mountains, impact craters, pits, and flows that may be the results of ice volcanism, along with myriad lakes near the polar regions. We have observed changes likely due to evaporation in one of these lakes and have witnessed the darkening of an area probably due to methane rainfall soaking the ground. Methane clouds dot the atmosphere, joined by blowing winds.

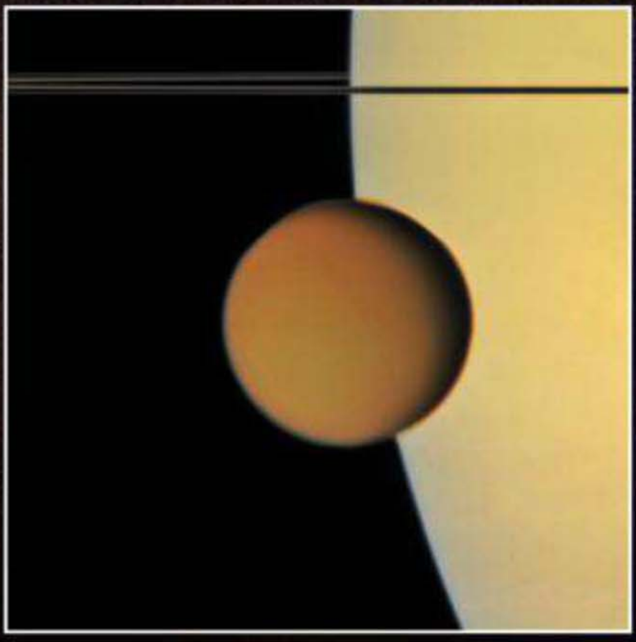
It turns out the moon also boasts another similarity to Earth. Large areas

Titan, the largest moon of Saturn, has turned out to be a strangely familiar place, full of lakes, clouds, and desert sand dunes. Michael Carroll for *Astronomy*

of Titan are covered with tens of thousands of sand dunes, much like those in many Earth deserts. Titan could have been the inspiration for the dusty, dry planet Arrakis in Frank Herbert's *Dune* — had that book not been written decades before Cassini first revealed the moon's hidden surface.

When the probe's first images revealed vast dark patches in the equatorial regions, it was unclear what they could be. Surface details show up best when Cassini's radar instrument uses its synthetic aperture radar (SAR) mode. However, we can only use SAR mode when Cassini flies close to Titan, so we can see only about 2 percent of the surface during each flyby.

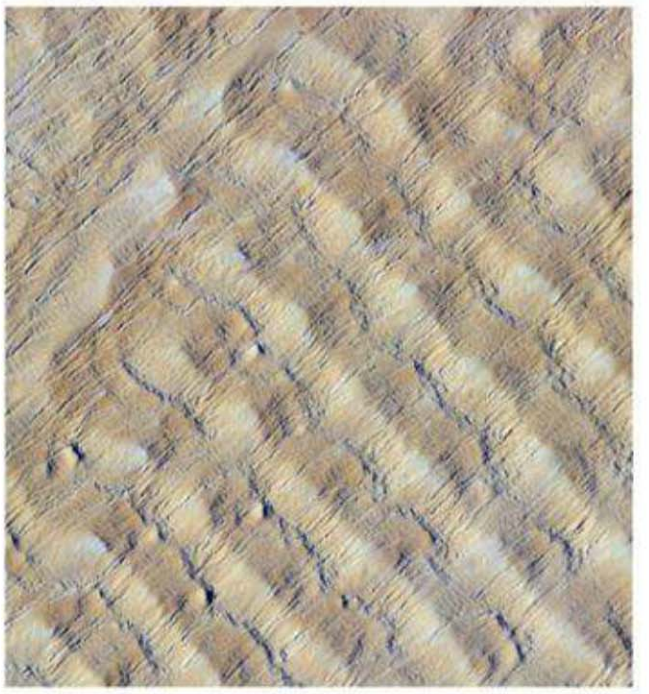
The first SAR pass missed much of the satellite's dunes because it surveyed high northern latitudes, far from the equatorial regions most filled with the dunes. It was during the second SAR flyby, in February 2005, that we first noticed patches of peculiar radar-dark parallel stripes against a radar-bright background. Geologists could not figure out what these land formations



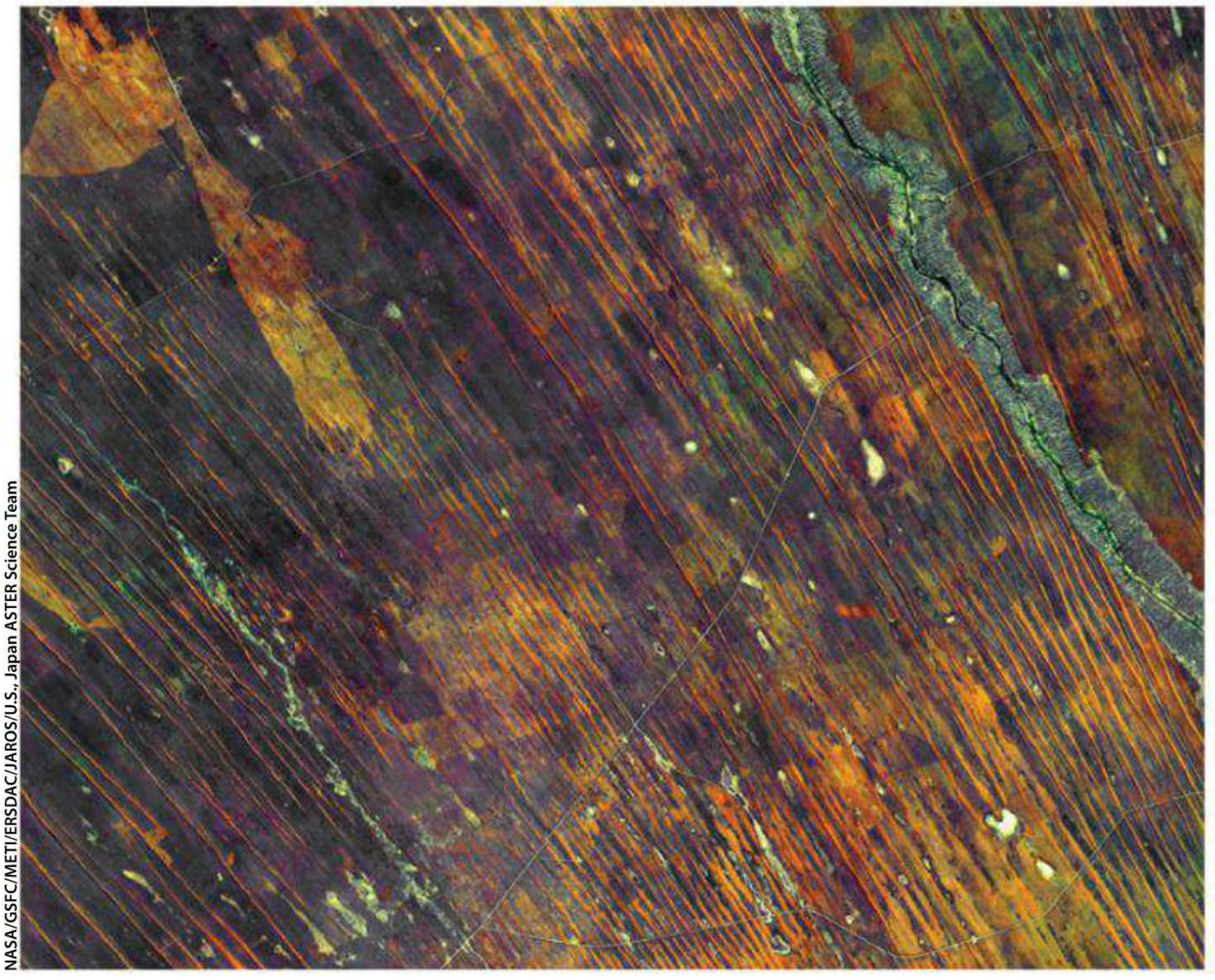
NASA/JPL/Space Science Institute

Titan's thick cloud and haze cover prevented scientists from learning any details of the moon's surface until recently.

Sand dunes come in three general classes. Barchans such as this one occur with loose collections of sand if the prevailing winds blow in a single direction. Daniel Mayer



Transverse dunes, like these in Niger, form under similar conditions as barchans, but require much more sand. (Look closely to spot a tiny set of linear dunes crossing them.) NASA/Expedition 22 crew



NASA/GSFC/METI/ERSDAC/JAROS/U.S., Japan ASTER Science Team

These linear or longitudinal dunes in Namibia, formed when winds blow from two directions, are some of the largest on Earth. Linear dunes make up the bulk of Titan's thousands of dunes.

were, and someone nicknamed them "cat scratches" based on their appearance.

The scratches stop abruptly at the edge of Titan's largest impact feature, Menrva. Clearly, the crater's topography created an obstacle for the scratches, and the possibility that they could be wind-formed dunes seemed the most reasonable option. Any doubts vanished when we obtained SAR images in October 2005 showing Titan's equatorial sand seas for the first time. The long, dark ridges of the dunes are close together, except where they encounter a topographic obstacle and divert around it in a teardrop pattern, something common to Earth's deserts. Indeed, it looks as if Titan's surface has been raked, like the sand in a Japanese garden.

Although the SAR data convinced us that dunes are present on Titan, questions remained. What is the "sand" actually made of? And more perplexingly, how do these dunes form under Titan's conditions? Although the moon has a dense atmosphere capable of sustaining winds, it's so far from the Sun that such surface winds were thought too weak to allow dunes to form. Gradually, however, the answers became clear.

Rosaly Lopes *is a senior research scientist at NASA's Jet Propulsion Laboratory in Pasadena, California, as well as the investigation scientist for the radar instrument on the Cassini probe.*

Sand and wind

So what is Titan's sand? The composition of materials on the moon's surface has been hard to determine because the same dense atmosphere that allows winds to blow also shields the surface from view. However, combining observations and models, the current preferred interpretation is that Titan's surface materials are complex hydrocarbons (molecules chained together by carbon atoms), nitriles (carbon molecules with a nitrogen atom attached), or perhaps both. The moon's lithosphere, or bedrock, is largely water ice.

Dune sands are dark in visible and infrared wavelengths, which is consistent with organic materials such as hydrocarbons. The radiometry mode of Cassini's radar instrument shows that the dune sands are probably fine-grained organic particles.

The source of the sand is likely the atmosphere itself: We know that organic "snow" composed of atmospheric haze particles constantly falls on Titan's surface, leading to vast deposits. These probably form sedimentary layers, which are later eroded by methane rainfall and flowing channels. Then, these channels, winds, or both carry the particles to sand sinks where they accumulate. Eventually, globe-encircling winds blow the sands into dunes.

The Cassini probe's radar instrument can use its synthetic aperture radar mode to best observe Titan's surface features. Here, long dunes and bright ridges show up on a relatively young crater-free surface. NASA/JPL

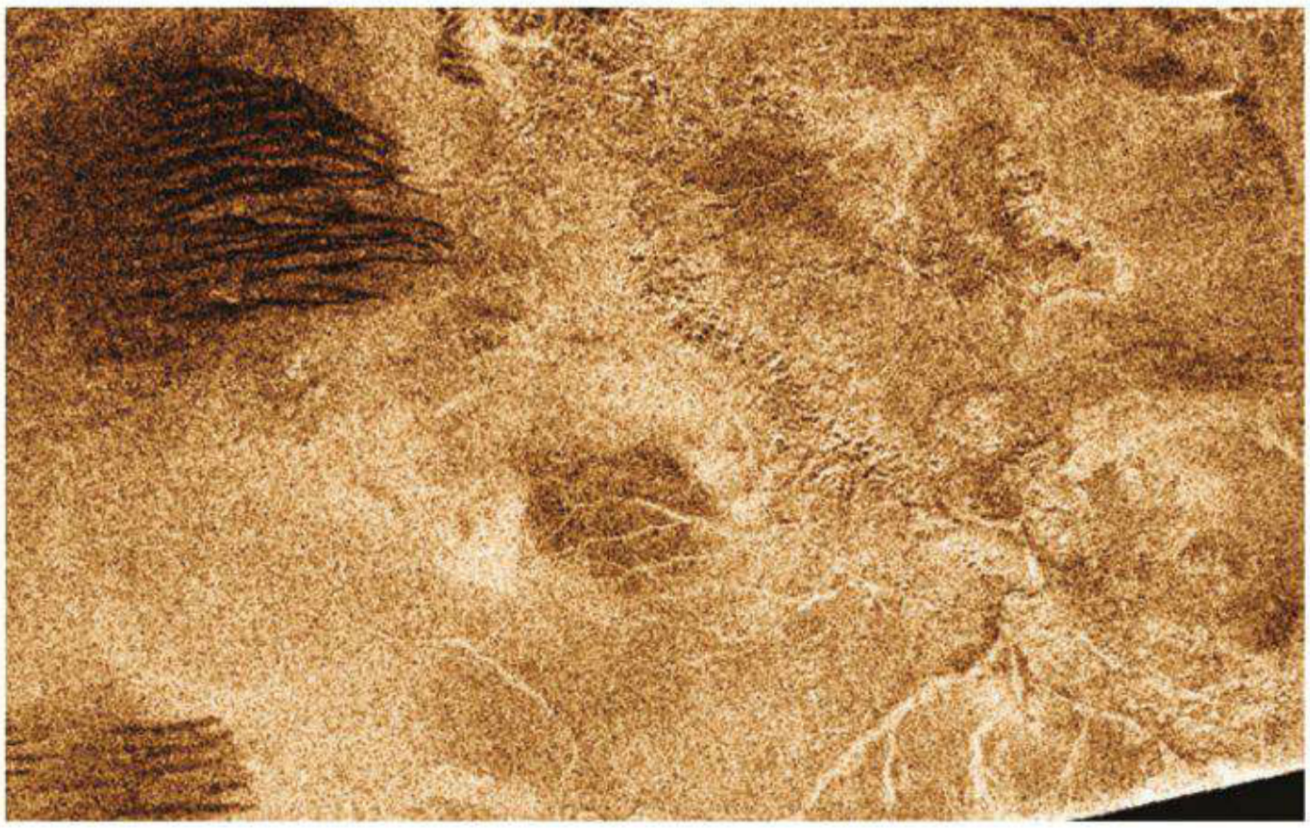
Dunes 101

Wherever in the solar system they may be, dunes form and move through the motion of individual sand grains that "jump" in a process called saltation. The process is a well-studied one on Earth, both in wind tunnels and out in the field. We know that the wind speed needs to be sufficiently high, and the sand dry, to send grains jumping forward. As each grain flies forward in the wind and hits the ground, it kicks up other grains from the surface. This process happens in a thin layer near the ground and can become self-sustaining. A dune may initially form where some small irregularity in ground topography traps a concentration of sand.

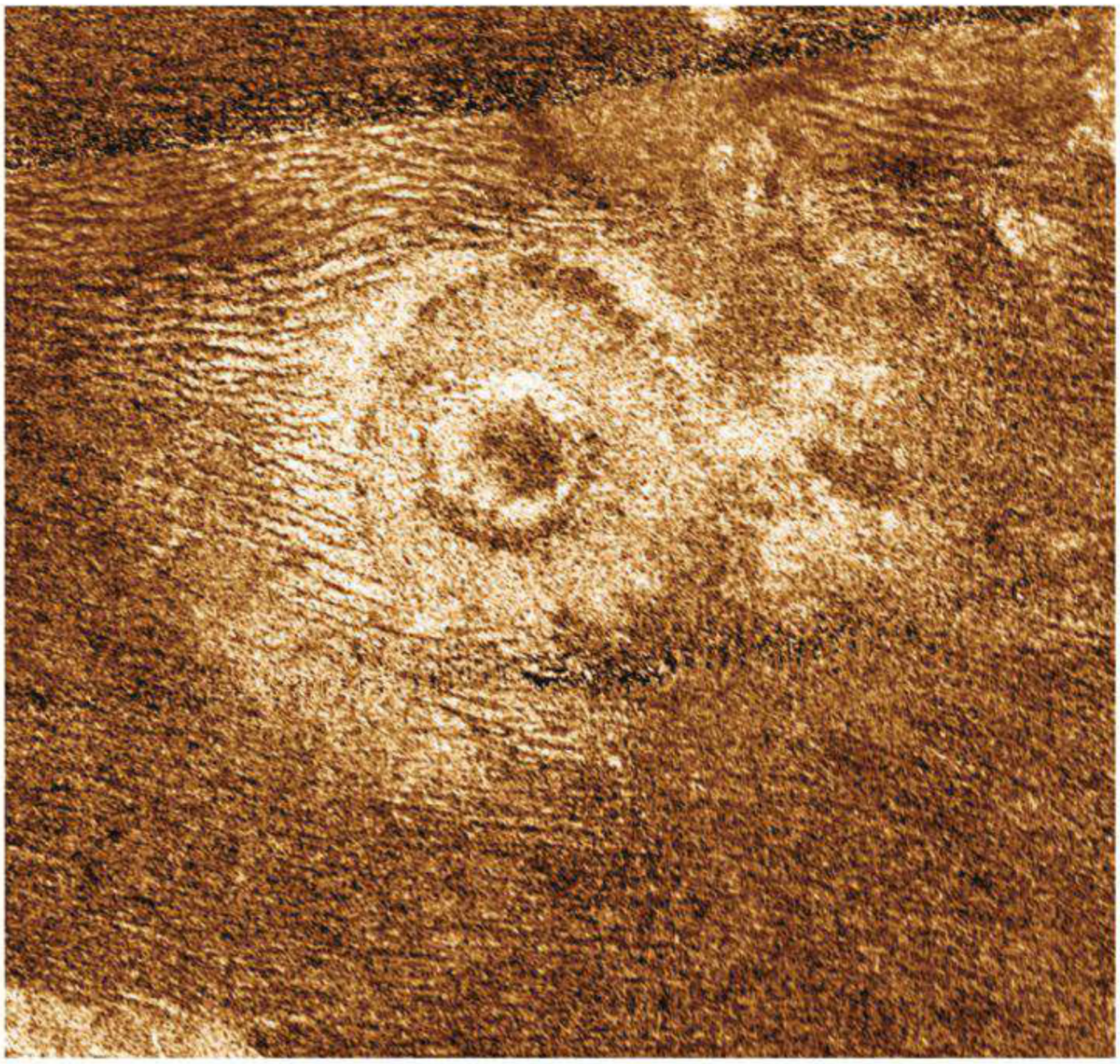
Once a dune exists, it often grows, sometimes over thousands of years. Depending on the wind's direction and constancy, dunes can take different forms. If the wind (and thus the sand transport) is in a single direction, it forms the most familiar pattern, called transverse dunes: long ripples perpendicular to the main wind direction.

However, if the sand supply is relatively low, the resulting dunes, known as barchans, will be isolated and crescent-shaped. In either case, the dune will have a steeper, well-packed side facing the wind direction called the stoss slope, and a loose, forward-moving downwind side called the slipface, or lee side. Desert peoples use this fact to their advantage, as they know it is much easier to walk on the stoss slope.

The largest dunes, the linear or longitudinal type, form when the wind comes predominantly from two directions, often due to seasonal changes. The net sand transport will occur roughly in the average direction of the strongest winds. About half the dunes on Earth are of this type, and they can stretch tens of miles, covering much of the Sahara, African, Australia's Simpson, and Arabian deserts. Some longitudinal dunes, especially those with a sinuous form, are also called seif dunes after the Arabic word for sword. Titan's thousands of dunes are of the longitudinal type.



The Cassini probe's synthetic aperture radar mode finally provided astronomers views of Titan's surface in 2005, and surprised them with the unusual "cat scratch" features seen here. NASA/JPL



Seeing that large craters and hills appeared to divert the "cat scratches," scientists figured out the odd features were likely wind-formed dunes similar to ones found in Earth's deserts. NASA/JPL-Caltech

Sand dunes on Earth and the dunes on Titan form remarkably similarly, with each revealing clues about its world's weather patterns and surface composition. The author took this photo during a trip to study the dunes of Namibia. Rosaly Lopes

TITAN BY THE NUMBERS

16 days
Length of orbit around Saturn

3,200 miles
(5,150 kilometers)
Diameter

1.5 bar
Surface air pressure

12 to 20 percent
Fraction of surface covered with sand dunes

16,000+
Dunes spotted by scientists

Dunes elsewhere

As Cassini acquired more data, we realized that dunes are common landforms on Titan, covering at least 12 percent of the surface, and maybe as much as 20 percent — or about 4 million square miles (10 million square kilometers). In comparison, dunes cover only 4 percent of Earth's surface. Mars and Venus also sport a number of dunes, but in small areas; on Mars, they cover only about 1 percent of the surface, and on Venus, it's even less.

Wind patterns in the thin martian atmosphere are fairly constant, forming transverse and barchans dunes. But although the Red Planet's surface is arid, dune fields are relatively rare, as wind speeds must be faster to move sand in air that's about 100 times less dense than air on Earth. The largest concentration of martian dunes forms a dark crescent surrounding the polar cap called the Northern Polar Erg. Other dune fields on Mars are small — in patches at the bottom of features such as Victoria Crater.

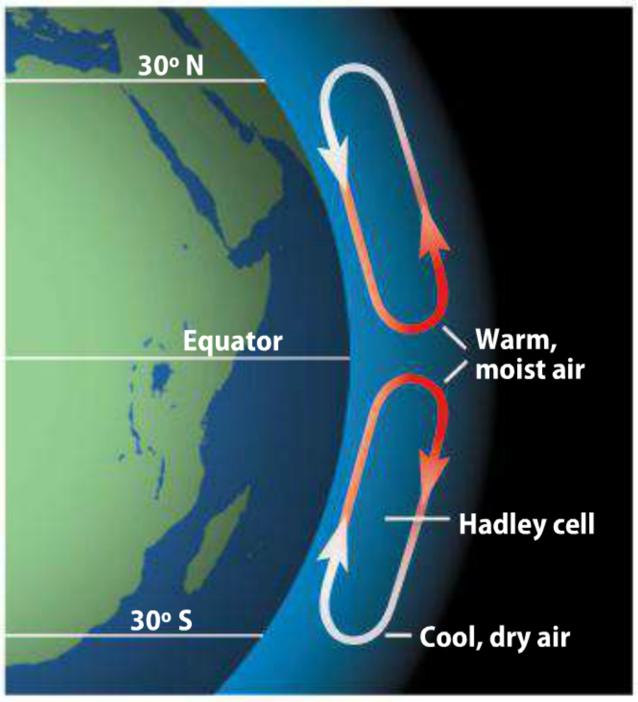
We have much higher-resolution images of Mars than we do of Titan, so it is likely that small dune fields on Titan exist as well, but have simply escaped detection. SAR imaging has covered only about half of Titan's surface, with a resolution of about 1,000 feet (300 meters) at best. We are a long way from knowing the surface of Titan as well as we know that of Mars.

The SAR images Cassini has acquired so far show more than 16,000 dunes on Titan. Most of these are within 30° of the equator, with a few isolated patches up to 55° away. The distribution implies that most of the sand supply, along with suitably dry conditions for dune formation, lies in the equatorial regions of Titan. On Earth, deserts are mostly located in two belts, about 20° to 30° north and south of the equator. Their location relates to air circulation in a meteorological model called the Hadley cell (see graphic on page 35). In simplified terms, the strong heat at the Earth's equator leads to an upwelling of moist air, forming large thunderstorms. The storms precipitate out the water from the rising air, so the downwelling side of the cell is therefore dry, leading to the arid belts on either side of the equator.

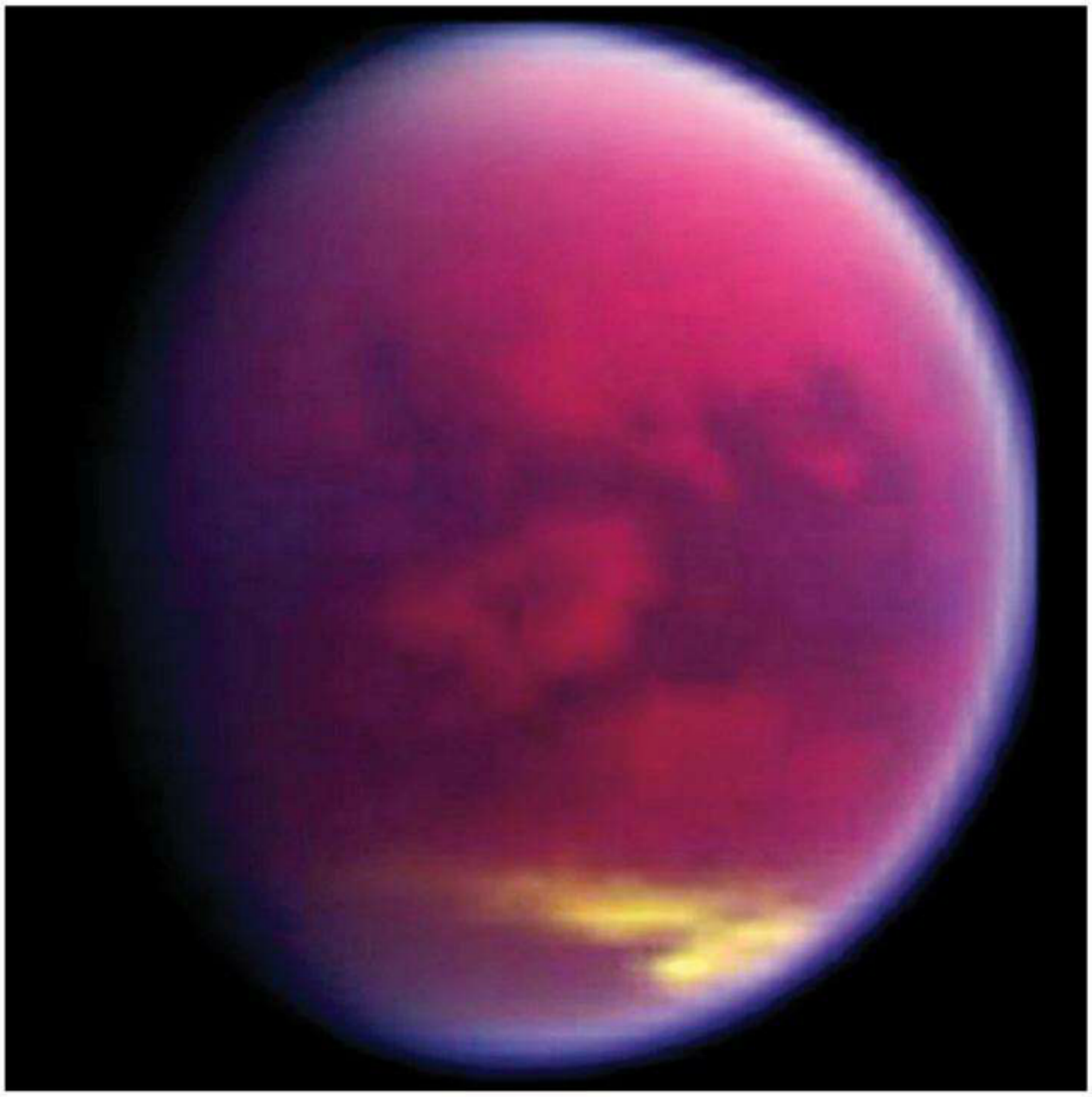
Dunes, therefore, can be indicators of climate. With that in mind, we plotted the distribution of Titan's dunes and made measurements of their sizes. Jani Radebaugh of Brigham Young University in Provo, Utah, and her students mapped thousands of Titan's dunes, measuring their lengths, widths, spacing, heights, and variations. In the equatorial sand seas, dunes are narrow, closely spaced, long, and straight, indicating abundant sand. At higher latitudes, near the edges of the sand seas, dunes have greater widths and spacing, and they tend to be shorter and more sinuous — these are the cat scratches we first spotted. By comparing these findings with studies of Earth's deserts, we can tell the higher latitudes must have a more limited supply of sand.

NASA/JPL-Caltech/University of Arizona/Cornell/Ohio State University

The Red Planet's conditions are also favorable for creating sand dunes, as seen in this Mars Reconnaissance Orbiter image of Victoria Crater.



A weather process modeled by the Hadley cell explains why desert regions occur about 20° to 30° away from Earth's equator. A similar process is at work on Titan, which helps distribute moisture. *Astronomy*: Roen Kelly



Continued studies of Titan throughout its various seasons will help scientists understand this mysterious world even better. In this false-color image of the moon, cloud cover appears yellow and its thick atmosphere appears magenta. NASA/JPL/University of Arizona/University of Nantes/University of Paris Diderot

The winds of Titan

As on Earth, the dunes of Titan offer clues about dominant winds, as the orientation and type of dunes indicate where the predominant breezes originate. Therefore, we initially concluded that winds on Titan blow from west to east. We geologists had no problem with this interpretation, but the atmospheric scientists didn't like it.

According to circulation models of Titan's atmosphere, winds should go the opposite way. Titan rotates in the same direction as Earth does, and the surface of these bodies transfers its angular momentum to the lower atmosphere, effectively pulling the atmosphere along. Titan's winds should blow from east to west, atmospheric scientists argued, like our familiar terrestrial trade winds. This "wind blowing backward" was quite a puzzle, and one of the atmospheric scientists even wondered if we had our images flipped around.

We had direct measurements of Titan's winds from the Huygens probe's descent, but not enough to solve the puzzle. As it landed near the equator, the probe's instruments indicated that winds blew toward the south-southwest. We knew that because Titan's dunes are longitudinal, they would likely be the result of bimodal winds — that is, two strong winds blowing from widely separated directions (more than 90°). The dunes align with the average sum of the winds, weighed by their strength.

Eventually, new atmospheric models for Titan were developed by Tetsuya Tokano from the University of Cologne in Germany and Ralph Lorenz from the Johns Hopkins University Applied Physics Lab in Laurel, Maryland. They took into consideration Titan's wind history throughout a solar orbit, which lasts 30 years, to come up with an answer. The scientists concluded that east-to-west winds, as predicted by the circulation models, generally blow on the moon, but that strong west-to-east winds occur briefly at the equinoxes. Although these winds are rare, they are strong at Titan's surface and better able to reach the velocities needed for particles to saltate — about 3 to 7 feet (1 to 2m) per second. This is what really answered the riddle.

As is often the case in science, it proved useful to have scientists from different fields working together. The models of atmospheric circulation on Titan also help explain why the dune fields are concentrated near the equator, as they predict that Hadley circulation transports humidity away from the equator and toward the polar regions. In order for sand to saltate and form dunes, the grains must be dry. And indeed, Titan's polar regions are home to the moon's giant methane lakes and seas.

Still mysterious

Despite all we've learned, Titan remains enigmatic. One exciting aspect of the Cassini mission is that we are observing something without precedent: the changing of seasons on another world.

When Cassini arrived at the saturnian system, it was winter in the north of the planet and its moons. Titan's northern polar regions were in darkness and its spectacular lakes and seas visible only to the radar. After equinox, in August 2009, the northern regions have come into light, and the local climate has begun changing. The Cassini probe should keep sending data until 2017, giving us time to observe even more behaviors on this new and strange world.

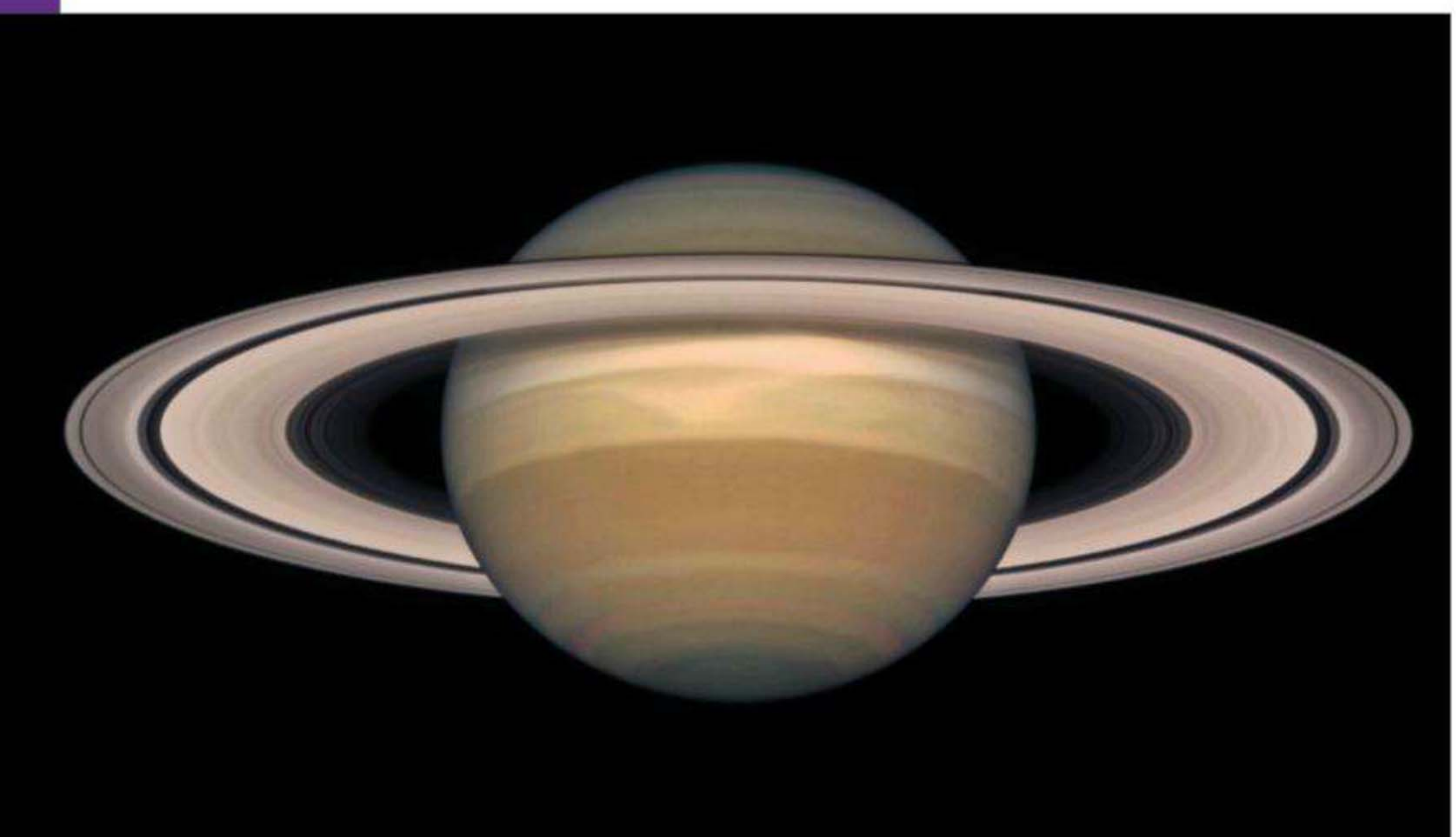
Test your skills telling Earth landscapes apart from alien ones at www.Astronomy.com/toc.

The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

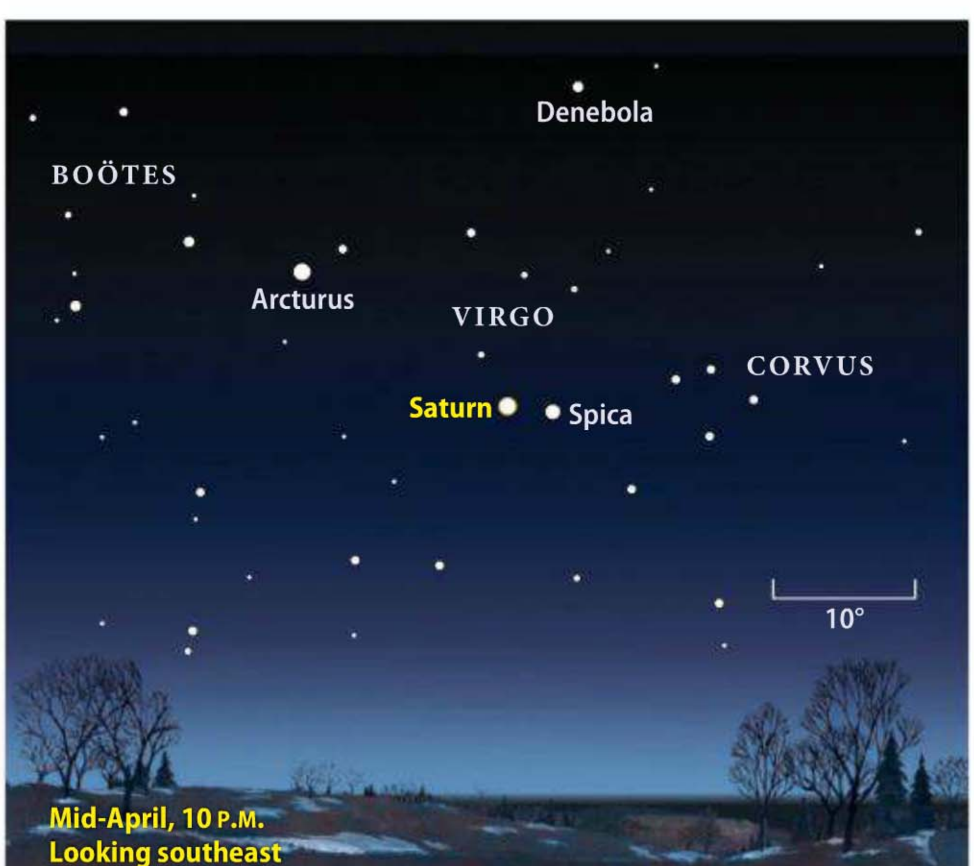
April 2012

Ringed world renaissance



Saturn's rings open wider than they've been since 2007, giving observers great views through small telescopes. NASA/ESA/Hubble Heritage Team (STScI/AURA)

Visible to the naked eye
Visible with binoculars
Visible with a telescope



Saturn peaks this month when it lies opposite the Sun in our sky and shines brightly in central Virgo near blue-white Spica. *Astronomy*: Roen Kelly

Saturn and Mars dominate the April sky nearly all night. Saturn reaches opposition and peak visibility in mid-April, a position Mars attained just last month. Saturn lies in Virgo while Mars resides one constellation to the west in Leo. These two spectacular planets aren't alone, however. The early evening sky features both Venus and Jupiter, which seem to herald the gorgeous planetary views later on. Venus stands out in particular, shining brightest this month and skimming the southern edge of the beautiful Pleiades star cluster.

Make your first target of the evening **Jupiter**. The giant planet hangs low in the west after sunset in early April. You can find Jupiter about 15° high one hour after the Sun disappears below the horizon. Shining brilliantly at magnitude –2.1, the planet stands out against the fading twilight colors. It remains on view until it sets around 10 P.M. local daylight time. A view through a telescope shows the gas giant's 34"-diameter disk, which won't reveal a lot of detail because of the low altitude.

With each passing night, Jupiter appears lower in the sky, a consequence more of the quickly advancing twilight on spring evenings than on anything the planet is doing. By the 15th, the giant world lies only 5° high an hour after sunset and dips below the horizon by the time twilight ends.

— Continued on page 41

— *Continued from page 36*

Jupiter disappears from view by the end of April as it heads toward its conjunction with the Sun in mid-May. But before it departs the evening stage, it has one final act worth noting. On April 22, a slender crescent Moon hangs just a few degrees above the planet in the bright twilight.

Look well above Jupiter and you can't miss dazzling **Venus**. Earth's planetary neighbor begins April only 1° below the famous Pleiades star cluster (M45). The view gets even better the following two nights when the planet passes through the cluster's southern outskirts. On the 2nd, Venus lies 0.6° due south of 4th-magnitude Electra (17 Tauri). The following night, the planet passes 0.3° south of 4th-magnitude Atlas (27 Tau).

Venus shines at magnitude –4.5 during the encounter, which makes it 100 times brighter than the combined glow of all the cluster's stars. The close pairing between the planet and the Pleiades promises to be one of the most engaging scenes in this spring's sky. The best views will come through binoculars or a telescope operating at low power.

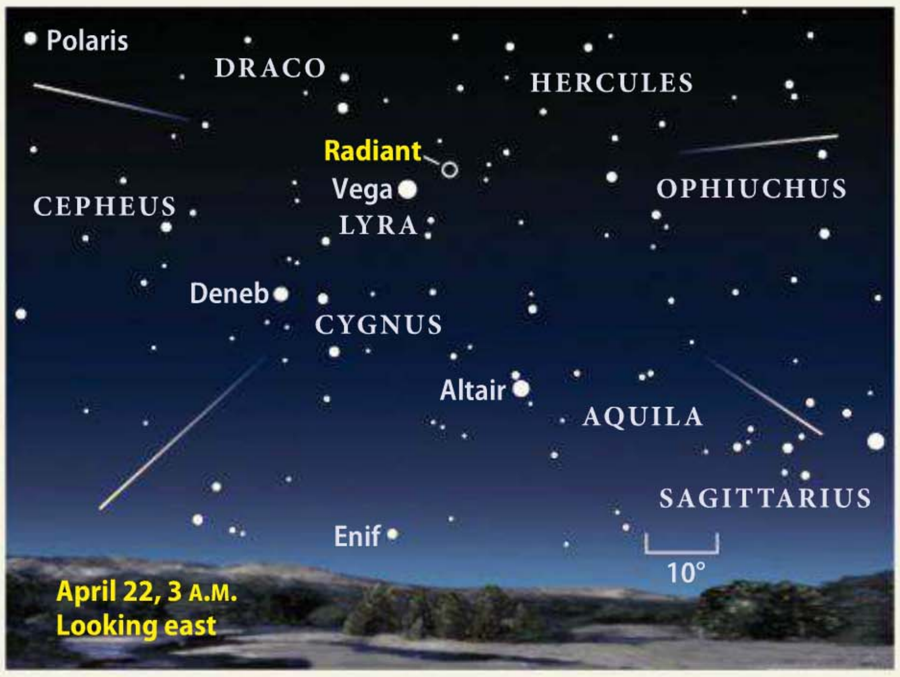
Venus moves quickly relative to the background stars of northern Taurus this month. From its perch near M45 in early April, it races eastward and ends the month just 3° shy of 2nd-magnitude Beta (β) Tauri, the star that marks the northern horn of the Bull.

Venus stands so high in the west after sunset because it reached greatest elongation from the Sun in late March. The planet remains at least 40° east of our star throughout April and sets after 11 P.M. local daylight time. And as bright as it appears next to the Pleiades early this month, it grows even brighter. By the 30th, it gleams at magnitude –4.7, the brightest it gets during this evening apparition.

The view of Venus through a telescope changes dramatically

Martin Ratcliffe *provides professional planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Lyrid meteor shower peaks before dawn April 22. With no Moon in the sky, viewing conditions should be perfect. *Astronomy*: Roen Kelly

April's shower reigns over a moonless sky

Barring bad weather, early January's Quadrantid shower gets the meteor-viewing year off to a rousing start. But then the sky settles down for a long winter's nap. The longest meteor drought of the year doesn't end until the Lyrid shower picks up in mid-April.

This shower remains active from April 16 to 25 but climbs to a fairly sharp peak the night of April 21/22. Under a clear, dark sky, observers typically spot about 20 meteors per hour at the peak. (Although rates have spiked as high as 90 per hour, that hasn't happened since 1982.)

Conditions this year should be ideal. New Moon occurs April 21, so our satellite's glare won't be around to cause interference. The meteors appear to radiate from the constellation Lyra, which lies in the northeastern sky in late evening and passes nearly overhead shortly before dawn.

Rising Moon

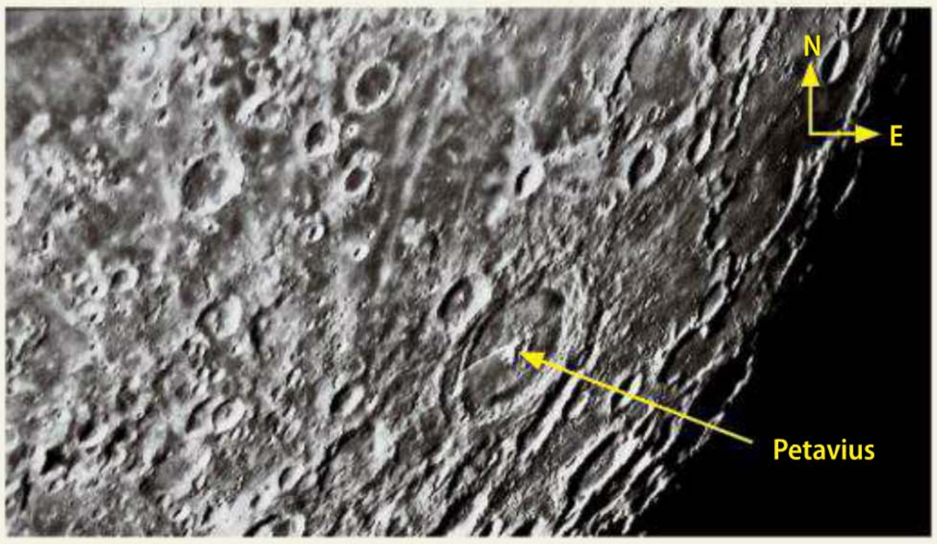
Lunar sunset provides a fresh perspective

Probably 90 percent of lunar observers view the Moon during its waxing phase. The period between New and Full Moon coincides with the time our satellite hangs in the evening sky. As the phase wanes following Full Moon, our celestial neighbor doesn't rise until late evening or after midnight.

Take some time this month to explore the practically unexplored country of a waning Moon. Lunar craters and wrinkle ridges take on a decidedly fresh appearance under these reversed lighting conditions. As the Sun sets over these features, it lights them from the western side. Their western flanks appear outlined in white, unlike the familiar black we see at lunar sunrise.

Although it is almost invisible in the days leading up to Full Moon, the crater Petavius is easy to spot in the lunar southeast late on the evening of April 7. The crater spans 110 miles, which makes it the biggest impact scar on this part of the Moon. Its center sports a complex of brighter peaks that stand above a distinct valley whose southern flank is lit up. The valley disappears under the rim's shadow the next night as lunar sunset darkens this region.

Take a quick look farther north to Mare Crisium and view the snaking wrinkle ridges lined with white on their western sides and shadows on the east. Return to the area during the waxing Moon April 23 and compare your impressions. The shadow of Petavius' central massif now reaches the bright western walls. Shadows retreat by the 24th to reveal the valley outlined by darkness instead of the light we saw in early April.



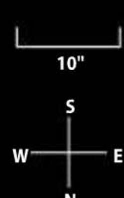
The large crater Petavius features a central mountain chain and several dark patches on its floor. *Consolidated Lunar Atlas*/UA/LPL

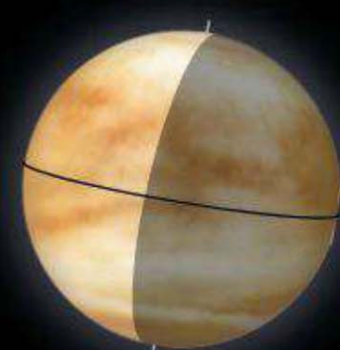
Planets in April 2012

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects dur

MOON PHASES

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

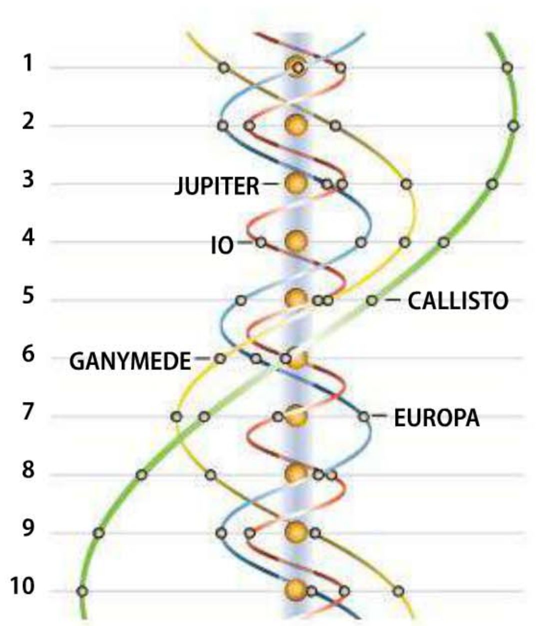


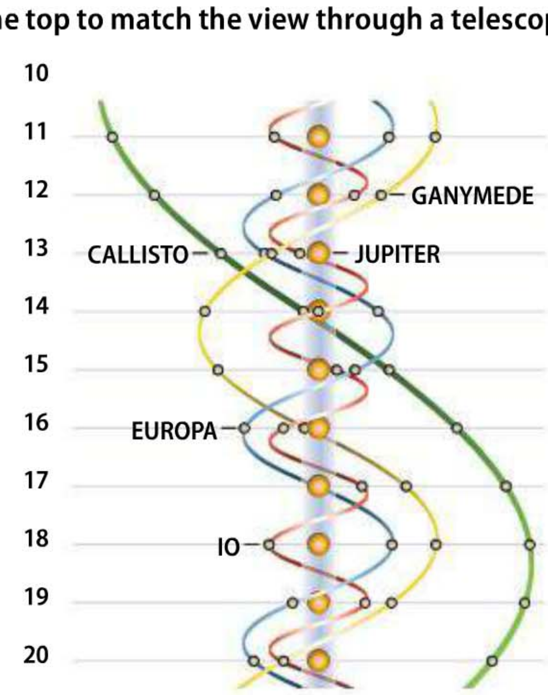


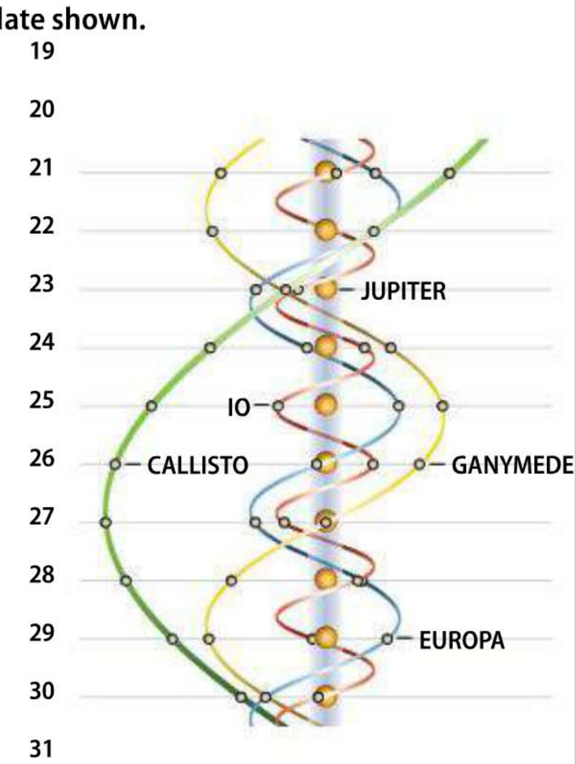
PLANETS	MERCURY	VENUS	MARS	CERES
Date	April 15	April 15	April 15	April 15
Magnitude	0.4	–4.6	–0.4	8.9
Angular size	8.4"	29.6"	11.3"	0.3"
Illumination	40%	40%	94%	100%
Distance (AU) from Earth	0.801	0.564	0.828	3.847
Distance (AU) from Sun	0.467	0.720	1.649	2.859
Right ascension (2000.0)	23h56.4m	4h29.0m	10h25.7m	2h06.8m
Declination (2000.0)	–2°30'	26°09'	12°45'	6°47'

Jupiter's moons

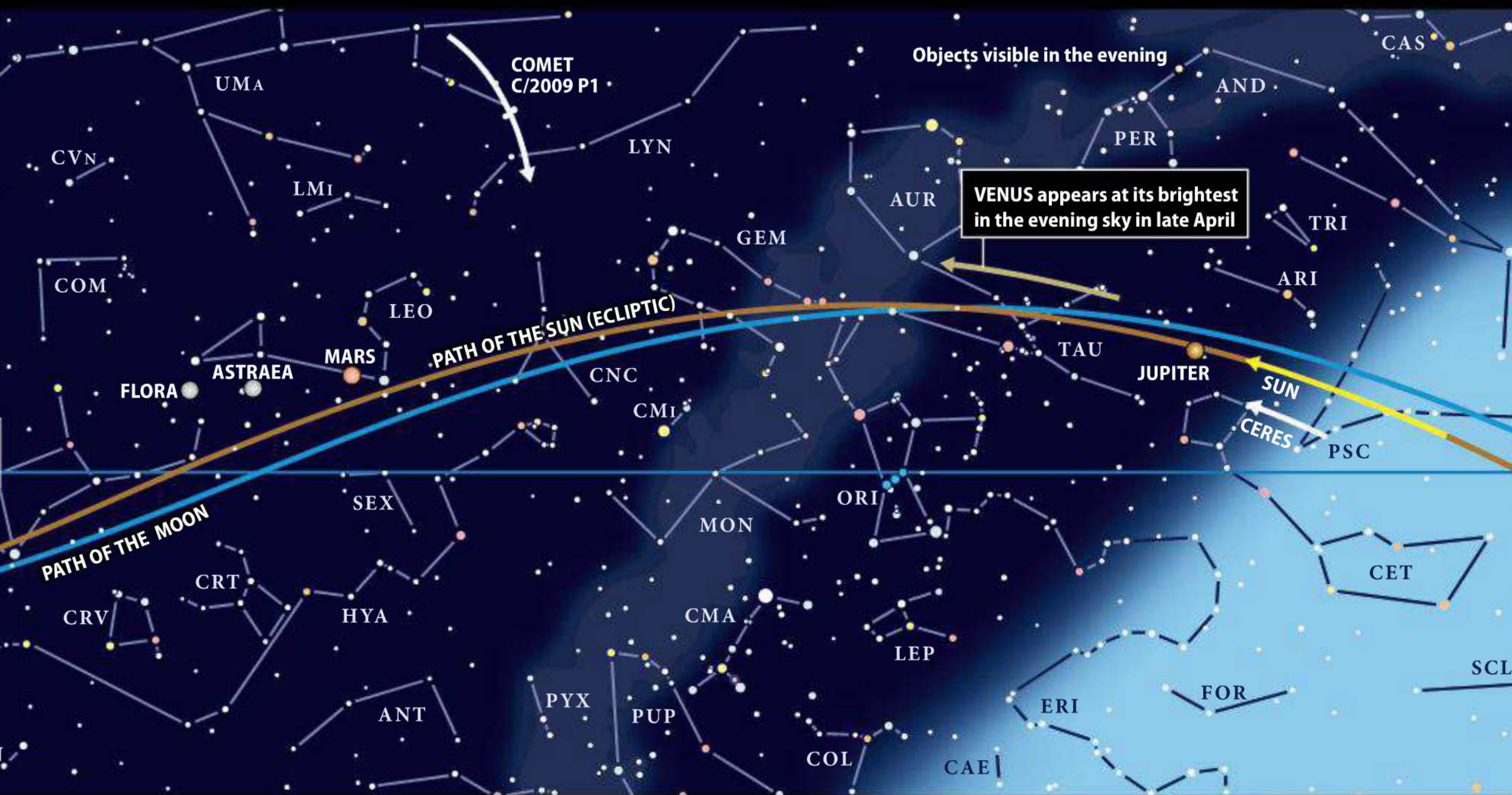
Dots display positions of Galilean satellites at 10 P.M. EDT on the date shown.
South is at the top to match the view through a telescope.



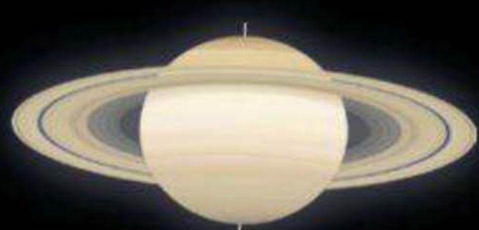




ring the month.



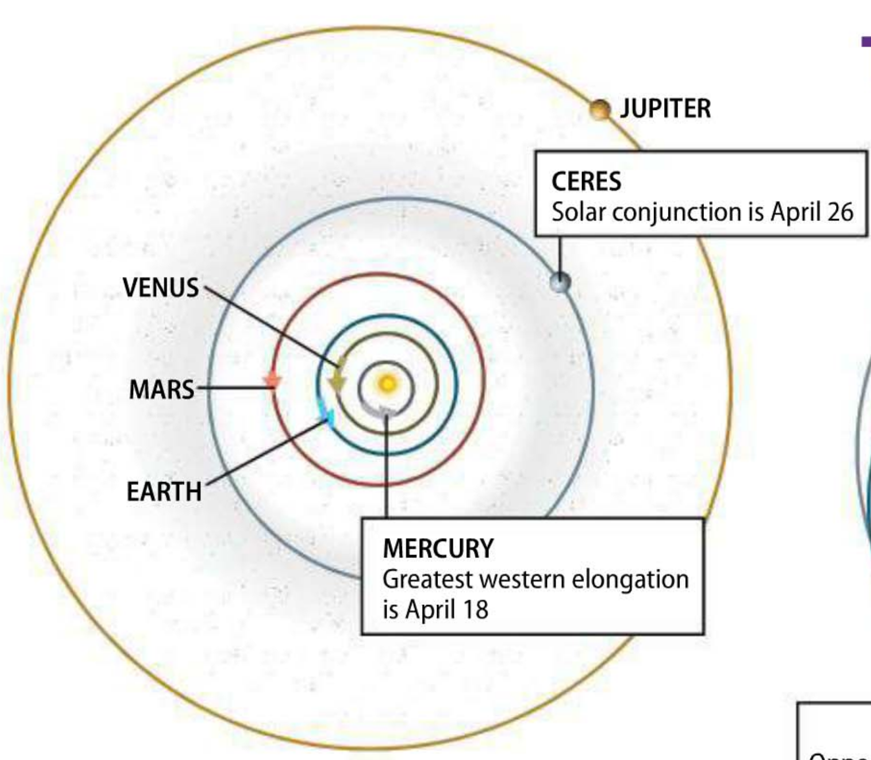
Illustrations by *Astronomy*: Roen Kelly

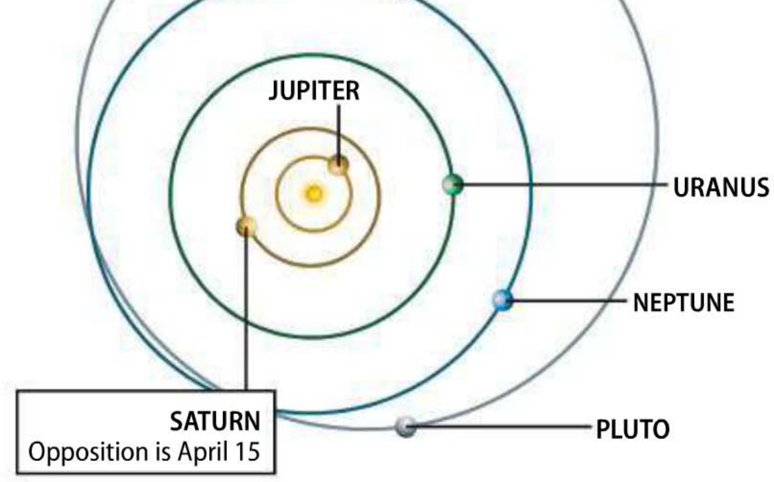


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
April 1	April 15	April 15	April 15	April 15
–2.1	0.2	5.9	7.9	14.1
33.9"	19.1"	3.4"	2.2"	0.1"
100%	100%	100%	100%	100%
5.813	8.720	21.013	30.593	31.924
4.990	9.722	20.071	29.999	32.213
2h43.9m	13h40.7m	0h21.4m	22h17.9m	18h39.7m
14°57'	–7°29'	1°34'	–11°11'	–19°13'

The planets in their orbits

Arrows and dots show planets' positions during April.





The all-sky map shows how the sky looks at:
midnight April 1
11 P.M. April 15
10 P.M. April 30

Planets are shown at midmonth

How to us
latit

Magnitudes
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

e this map: This map portrays the sky as seen near 35° north tude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly

Quick fact: Brilliant Venus slides through the Pleiades star cluster April 2 and 3, providing stunning views through binoculars or a telescope at low power.

Astronomy magazine

April 2012

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Calendar of events

3 Mercury is stationary, 2 A.M. EDT

The Moon passes 9° south of Mars, 11 P.M. EDT

6 Full Moon occurs at 3:19 P.M. EDT

7 The Moon passes 6° south of Saturn, 10 A.M. EDT

The Moon is at perigee (222,646 miles from Earth), 12:59 P.M. EDT

9 Asteroid Vesta is in conjunction with the Sun, 8 P.M. EDT

10 Pluto is stationary, 11 A.M. EDT

13 Last Quarter Moon occurs at 6:50 A.M. EDT

15 Mars is stationary, 8 A.M. EDT

Saturn is at opposition, 2 P.M. EDT

Special observing date

15 Saturn reaches its 2012 peak today, shining at magnitude 0.2 and appearing 19.1" across through a telescope (the rings span 43.3").

16 The Moon passes 6° north of Neptune, 11 A.M. EDT

Venus passes 10° north of Aldebaran, 9 P.M. EDT

18 Mercury is at greatest western elongation (27°), 1 P.M. EDT

The Moon passes 8° north of Mercury, 10 P.M. EDT

19 The Moon passes 6° north of Uranus, 4 A.M. EDT

21 New Moon occurs at 3:18 A.M. EDT

Mercury passes 2° south of Uranus, 10 P.M. EDT

22 Lyrid meteor shower peaks

The Moon is at apogee (252,537 miles from Earth, 9:48 A.M. EDT

The Moon passes 2° north of Jupiter, 3 P.M. EDT

24 The Moon passes 6° south of Venus, 10 P.M. EDT

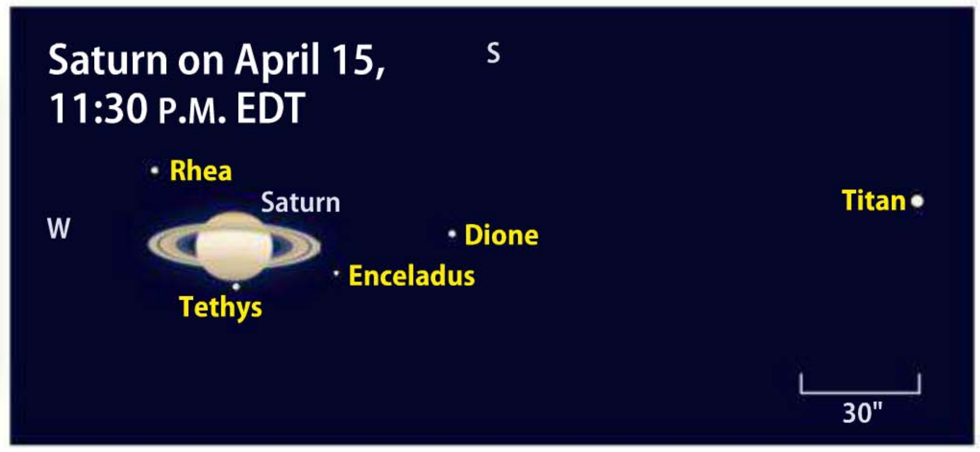
26 Asteroid Ceres is in conjunction with the Sun, 10 A.M. EDT

29 First Quarter Moon occurs at 5:57 A.M. EDT

30 Venus is at greatest brilliancy (magnitude –4.7), 4 A.M. EDT

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Venus (west)	Mars (southwest)	Mercury (east)
Mars (southeast)	Saturn (south)	Saturn (southwest)
Jupiter (west)		Uranus (east)
Saturn (east)		Neptune (southeast)



Saturn at opposition provides great views of its disk and rings, but don't forget to look for the planet's brighter moons. *Astronomy*: Roen Kelly

during April. The planet comes much closer to Earth and its apparent diameter swells nearly 50 percent, from 25" to 37". Over the same period, Venus' phase wanes sharply, dropping from nearly half-lit on the 1st to barely one-quarter illuminated on the 30th.

As darkness falls these April evenings, **Mars** stands two-thirds of the way from the southeastern horizon to the zenith. It dominates the background stars of its host constellation, Leo the Lion. The Red Planet shines at magnitude –0.4 at midmonth, easily besting Leo's brightest star, Regulus. Mars moves westward relative to the starry backdrop until April 15, when it approaches within 4° of Regulus, before resuming its normal easterly motion.

Notice the vivid color contrast between Mars and Regulus. The former appears orange-red because its surface, which contains lots of iron oxide, or rust, reflects that color of sunlight. The latter shines blue-white because hot stars preferentially radiate that hue.

Now just one month past opposition, Mars is a fine object even through small telescopes. The best views come early in the month when the planet appears larger. Mars' apparent diameter shrinks from 13" on April 1 to a still-respectable 10" by the 30th. Superior views also come shortly after darkness falls when Mars lies highest in the sky and its light passes through less of Earth's image-distorting atmosphere.

Mars rotates on its axis once every 24.6 hours. This means that if you observe at the same time each night, the planet will seem to rotate backward. (To put it another way, if you see a feature on Mars' central meridian at a specific time one night, it won't return to the same central position until 36 minutes later the next night.)

The prominent dark feature Syrtis Major provides a good example. At 11 P.M. EDT April 7, Syrtis Major is just rotating out of view. At the same time April 13, it appears nearly dead center on the planet's disk. And a week after that, Syrtis Major starts to rotate onto the visible disk at 11 P.M. EDT and remains in view until Mars sets around 4 A.M. local daylight time.

Saturn puts on quite a show in April. The ringed planet lies opposite the Sun in our sky on the 15th, which means it rises at sunset and remains visible all night long. An outer planet also lies closest to Earth at opposition and so appears brightest; in

Comet search

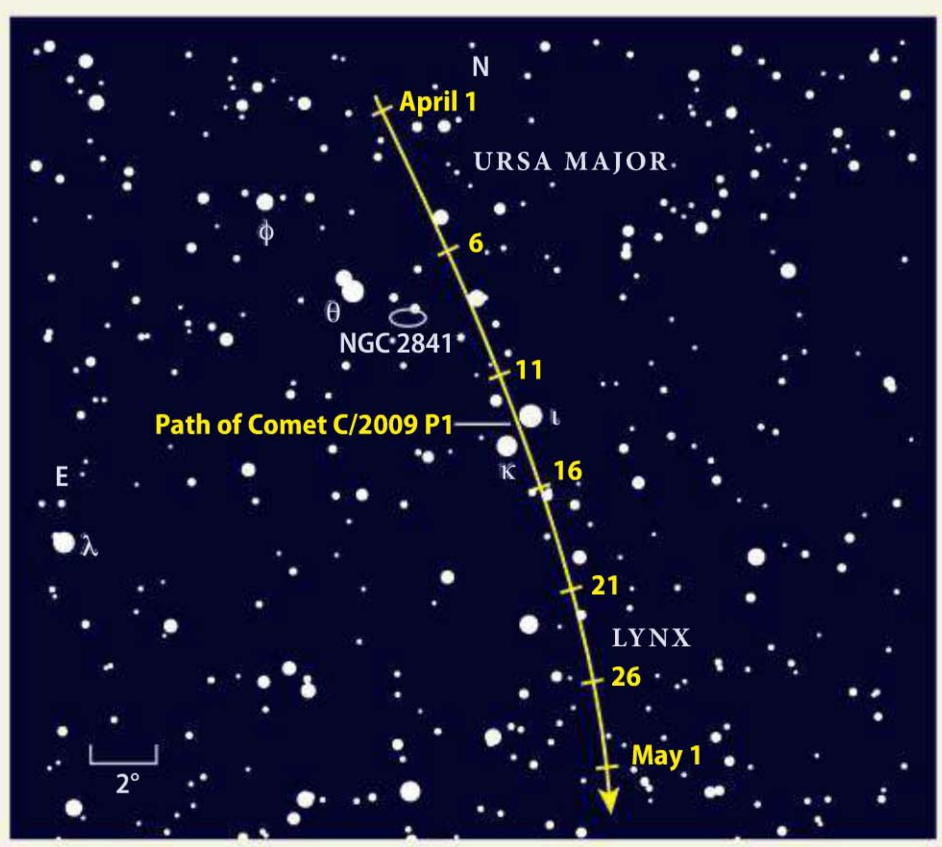
Celestial visitor points to a bright galaxy

Comet C/2009 P1 (Garradd) has graced our Northern Hemisphere sky for a year now, going about its business in a consistent if not spectacular way. Although the comet is now cruising back to the depths of the solar system, it remains a nice sight throughout these spring nights. It rides high in the evening sky and stays visible from dusk to dawn, so you can target it whenever you're observing. If it follows astronomers' predictions, the comet should fade only from 8th to 9th magnitude in April. It may be a bit faint for binoculars to deliver good views, but a telescope shows it well.

Comet Garradd is now on a southward trajectory through the front legs of Ursa Major the Great Bear. It passes just 2° east of the magnitude 9.2 spiral galaxy NGC 2841 at the start of April's second week. Many deep-sky observers rank this galaxy among the finest that French astronomer Charles Messier didn't see.

Messier observed and recorded some 44 comets during his 18th-century observations, but he also turned up lots of other fuzzy-looking celestial objects. Because he was interested only in the comets, however, he compiled a catalog of the imposters so future observers wouldn't be led astray. As you view Comet Garradd, compare its brightness, shape, and level of detail with NGC 2841. Would you mistake the galaxy for a comet?

Although the comet passes closest to the galaxy a couple of nights after Full Moon, it's worth hopping back and forth between the two at other times as well. Each will provide more than a few minutes of interest. You might also want to target the visitor from the outer solar system the evening of April 13. That night, the comet passes between Iota (ι) and Kappa (κ) Ursae Majoris, which together represent one of the Great Bear's feet.



Comet C/2009 P1 (Garradd) slides through southern Ursa Major this month, passing near the fine spiral galaxy NGC 2841. *Astronomy*: Roen Kelly

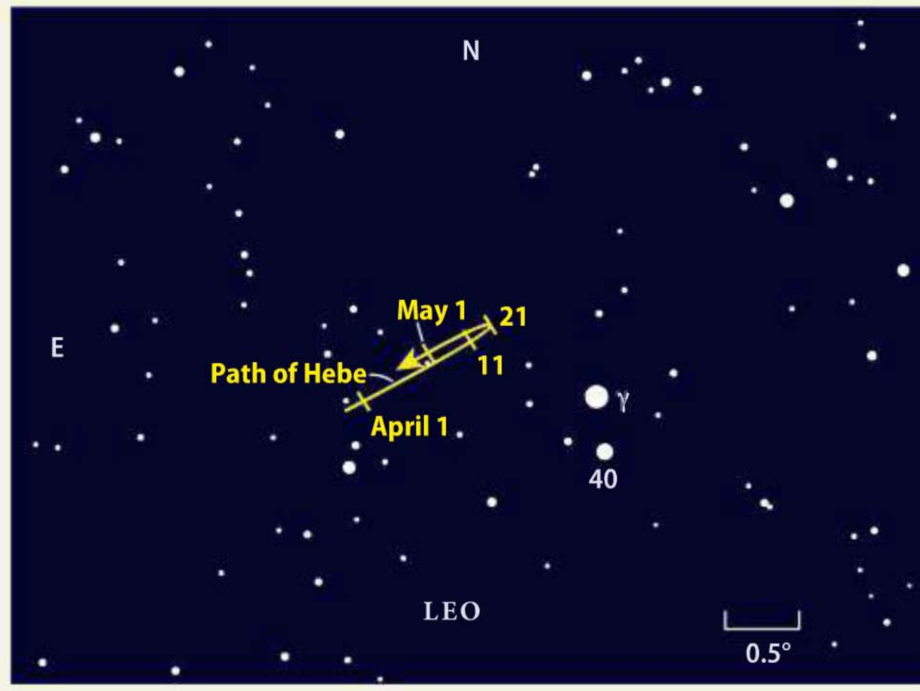
Locating **asteroids**

Hebe gives Leo the Lion a sleepless night

Main-belt asteroid 6 Hebe rides on the back of Leo the Lion all month. This region lies high in the southeastern sky on April evenings, not far north of the blue-white star Regulus and the orange-hued planet Mars. Just like the Red Planet, the asteroid completes its retrograde loop this month and then starts heading eastward relative to the background stars.

This celestial dance keeps the 120-mile-wide Hebe within 1.5° of Algieba (Gamma [γ] Leonis), a lovely golden-orange pair that appears as the brightest star in the curve of Leo's Sickle asterism. Pump up your telescope's power past 120x to split this 4"-wide binary system. Beginners commonly mistake the secondary as 40 Leonis, a 5th-magnitude star less than a Moon's width south of Gamma.

Next, nudge your scope east of Gamma and use the chart to pick out 10th-magnitude Hebe from the distant background stars. To positively identify the asteroid, you need to detect its movement. Hebe's motionless masquerade around midmonth will make this task harder, but you should see it by April's final week.



Hebe joins Algieba (Gamma [γ] Leonis) throughout April as the asteroid completes its retrograde loop. *Astronomy*: Roen Kelly

Saturn's case, it peaks at magnitude 0.2. That makes it nearly a full magnitude brighter than Spica, the luminary of the planet's host constellation, Virgo the Maiden. Spica lies 5° southwest of Saturn all month. A Full Moon appears near both the night of April 6/7.

The view of Saturn through a telescope impresses novices and seasoned observers alike. The planet's disk appears noticeably flattened, measuring 19" across the equator but only 17" from pole to pole at opposition. (Saturn's equatorial bulge arises from its gaseous nature and fast rotation.)

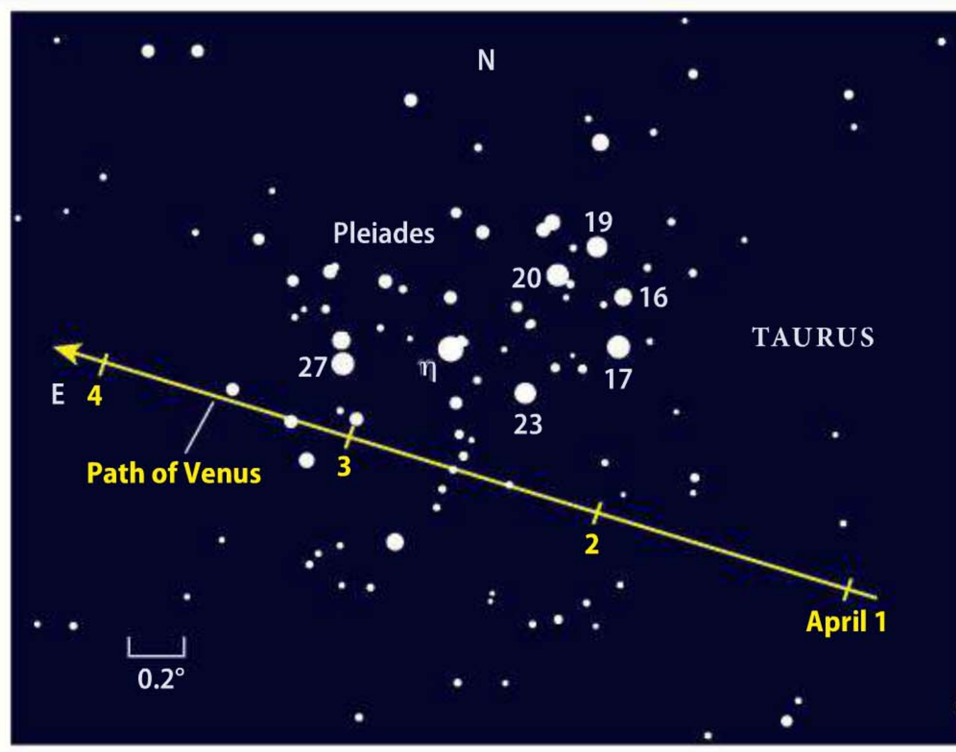
You should check Saturn's disk for any possible storm systems. Although they are quite rare, a large one captured observers' attentions last year. Even small instruments revealed it as a distinct white spot. It grew more elongated as it was buffeted by the saturnian atmosphere's high winds.

But the true visual treat comes from viewing Saturn's ring system, which looks pretty as a picture even through a small scope. The rings span 43" on the 15th, more than double the planet's disk, and tilt 14° to our line of sight. You should have little trouble spying the Cassini Division, a dark gap that separates the outer A ring from the broader and brighter B ring.

Small telescopes also reveal a handful of Saturn's moons. The biggest and brightest, 8th-magnitude Titan, orbits Saturn once every 16 days and shows up through any instrument. You can find this moon due south of the planet the evenings of April 2 and 18 and due north April 10 and 26.

A good 4-inch telescope reveals a trio of 10th-magnitude moons. Tethys, Dione, and Rhea lie well inside Titan's orbit and revolve around the planet much faster. (Tethys circles in 1.9 days, Dione in 2.7 days, and Rhea in 4.5 days.) You'll need an 8-inch or larger scope to pick up 12th-magnitude Enceladus, which orbits in 1.4 days and never strays far from the outer edge of the ring system.

Perhaps Saturn's oddest moon is two-faced Iapetus. One of its hemispheres is as bright as freshly fallen snow while the other is as dark as charcoal. And because it always keeps the same face pointed toward Saturn, earthbound observers see its brightness change by 2 magnitudes during its 80-day orbit.



Venus passes along the southern edge of the Pleiades star cluster (M45) the evenings of April 2 and 3. *Astronomy*: Roen Kelly

Look for it 2' due south of Saturn on April 6 when it glows at 11th magnitude. Then follow it as it heads toward greatest western elongation April 26, when it shines at 10th magnitude and lies 9' from the planet.

Distant **Neptune** returns to the morning sky in April. You can find it among the background stars of central Aquarius, low in the east-southeast shortly before dawn. Binoculars should bring the 8th-magnitude world into view.

Neptune's 6th-magnitude sibling, **Uranus**, hangs even lower in the predawn sky. On April 30, it lies 6° above the eastern horizon 45 minutes before sunrise.

Mercury reaches greatest elongation April 18, when it lies 27° west of the Sun. Unfortunately, spring mornings are notoriously difficult for viewing planets. The innermost world appears just 4° above the eastern horizon 30 minutes before sunrise from midnorthern latitudes. It shines brightly at magnitude 0.3, however, so you might spy it through binoculars against the bright twilight.

Turning clouds of darkness into stars of light

Small, dark, and ubiquitous, **Bok globules** offer astronomers an inside look at how low-mass stars form.

by Bruce Dorminey

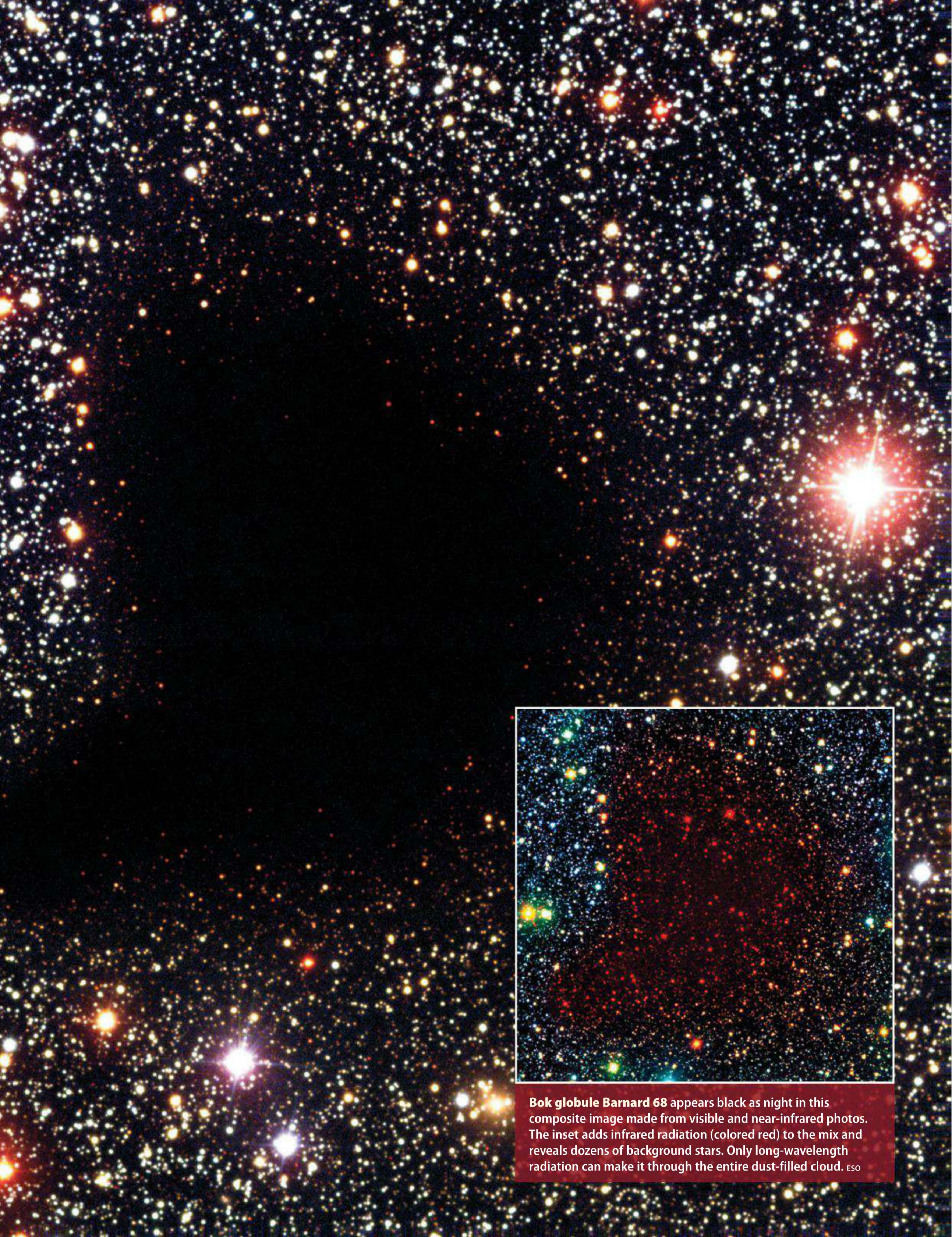
Their name alone is enough to conjure images of lava lamps and 1960s-era abstract art. But Bok globules are even stranger than that. They rank among the coldest, darkest, densest, and most mysterious clouds known in our galaxy.

Astronomers suspect these globules are the fragmented remnants of evaporated molecular clouds. If so, they hold many keys to understanding the early history of stars like ours. There's even an outside chance that our Sun originated in one.

The majority of cataloged globules lie within a few thousand light-years of Earth. Using current technology, observers have little trouble seeing them against a bright Milky Way background. But in the late 1940s, it wasn't so easy. That was when Dutch-born American astronomer Bart Bok first categorized these black clouds by painstakingly examining photographic plates.

Although the Milky Way Galaxy likely contains tens of thousands of Bok globules, astronomers have identified only 100 or so in our stellar neighborhood. "You can't do optical observations of them beyond a certain distance in the galactic plane because there's just too much dust in the way," says Mark Krumholz, an astronomer at the University of California, Santa Cruz. "I would be shocked if there weren't many more than we can see."

Frequent contributor **Bruce Dorminey** *is a science journalist and author of* **Distant Wanderers: The Search for Planets Beyond the Solar System** *(Springer, 2001).*



Bok globule Barnard 68 appears black as night in this composite image made from visible and near-infrared photos. The inset adds infrared radiation (colored red) to the mix and reveals dozens of background stars. Only long-wavelength radiation can make it through the entire dust-filled cloud. ESO

Several Bok globules appear in silhouette against the glowing clouds of the emission nebula IC 2944. The largest globule (top right) comprises two overlapping clouds, each of which spans about 1.4 light-years.
NASA/ESA/Hubble Heritage Team (STScI/AURA)

Not all Bok globules form stars. This one lies near the center of emission nebula NGC 281, not far from a cluster of massive young stars. Strong radiation and stellar winds from these behemoths likely will destroy this globule.
NASA/ESA/Hubble Heritage Team (STScI/AURA)

Bok originally described these objects as small, round, dark spots projected onto bright star-forming regions. They have typical diameters of roughly half a light-year, or some 30,000 astronomical units (AU). (One AU is the average distance between the Sun and Earth and equals approximately 93 million miles [150 million kilometers].)

These globules are much smaller than an average molecular cloud, which can span 100 light-years or more. Still, they dwarf our planetary system. If you placed the Sun at the center of a typical Bok globule, the dark cloud would engulf all the planets (which extend out to about 30 AU) and even the inner part of the Oort Cloud of comets. The globule's edge would reach more than 5 percent of the way to Proxima Centauri, our nearest stellar neighbor.

Although Bok globules are dense compared with an average parcel of interstellar medium, they seem downright ephemeral by earthly standards. Air at sea level, for example, is 100 billion times denser than material in a globule. To an astronaut inside a globule, however, the universe would appear pitch black. As astronomer Jonathan Williams of the University of Hawaii at Manoa points out, these objects are large enough that the total amount of material between an astronaut and the stars outside the globule would be enormous.

Holes in the heavens

German-English astronomer William Herschel first noticed dark nebulae around 1785 during his surveys of the Northern Hemisphere sky. Herschel dubbed them "holes in the heavens" and believed they marked tunnels through which he could see beyond the stars.

In the late 19th century, University of Chicago astronomer Edward Emerson Barnard photographed and cataloged a few hundred of these nebulae scattered throughout the Milky Way. His observations started to dispel the notion that the objects were holes because he could discern their edges. He noted that they resembled dark clouds.

More than **50 percent** of the known Bok globules appear to be creating stars.

Then, in the 1940s, Bok examined the best available photos of star-forming regions and focused on the small, round, and particularly dense objects in Barnard's catalog. Bok coined the term *globule* and suggested that they might be sites where stars are forming. It took a few decades before most astronomers came around to the same view. Today, Bok globules play a vital role in understanding how low-mass stars form. Yet their scientific importance stretches beyond this realm and into constraining the initial mass function — the relation between a globule's starting mass and the mass of the star that it ultimately produces — and illuminating the nature of astrochemistry on dust grains in cold dark clouds.

But these insights beg the question: Where did the globules themselves originate? "One theory is that Boks formed from long filamentary dark clouds, like a string of pearls," says astrophysicist David Ciardi of the California Institute of Technology in Pasadena. "The filamentary dark

A Bok globule sits in front of the 2.5-million-year-old star cluster Trumpler 14 inside the Eta Carinae Nebula (NGC 3372). For every trillion photons of visible light that enter a globule like this, only one of them makes it all the way through. NASA/ESA/N. Smith (UC, Berkeley)/Hubble Heritage Team (STScI/AURA)

Nicknamed the "caterpillar," this Bok globule resides in the mighty Eta Carinae Nebula (NGC 3372). The globule's glowing edge suggests that the massive stars surrounding it will evaporate its gas and dust before it can form a star. NASA/ESA/N. Smith (UC, Berkeley)/Hubble Heritage Team (STScI/AURA)

clouds get disturbed, and the globules inside get 'squeezed' out of the chain." Two favorite targets of backyard observers and astroimagers — the Horsehead (B33) and Eagle (M16) nebulae — may contain gaseous cores that eventually could split off into Bok globules.

From cloud to star

More than 50 percent of the known Bok globules appear to be creating stars. Still, star formation inside the globules seems incredibly inefficient. At least 90 percent of a globule's gas gets cast off or dispersed before a star forms. This low efficiency means a Bok globule containing 10 times the Sun's mass typically produces a star the size of the Sun or smaller.

"Bok globules are a good lab for studying isolated star formation," says Phil Myers, an astronomer at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. "Although most low-mass stars form in clusters, stellar clusters are very turbulent and confusing places where it's difficult to pick out one star-formation event from another. By studying Boks, we're going to understand more about how protostars form."

Stars form from the fragmentation and eventual collapse of interstellar molecular clouds. Scientists know that a supernova explosion, turbulence generated by the winds of hot, massive stars, and density-wave fluctuations in the galaxy's spiral arms can initiate such collapses. Yet researchers still debate whether isolated molecular clouds such as Bok globules need an external trigger to start the star-formation process or if gravity alone can win out and cause the collapse.

"I think they can collapse on their own; there's always turbulence and gravity in the cloud," says astronomer Hector Arce of Yale University in New Haven, Connecticut. "A supernova shock or stellar outflow from another star can help, but it's not necessary."

Darkness in Barnard 68

In a 1947 paper published in *The Astrophysical Journal*, Bok and his Harvard College Observatory colleague and co-author Edith Reilly noted several globules set against the bright glow of the Lagoon

E.T. — phone here

The quest for clues to the formation of Sun-like stars inside Bok globules could bring us face to face with our own future. Will our civilization eventually evolve from a race of biological also-rans into an artificial race of highly intelligent, self-replicating — even self-repairing — machines?

Such artificial intelligence (AI) may be drawn to the thermodynamic efficiencies that the extremely low-temperature conditions in a Bok globule can provide. At least that's the view of astronomer Seth Shostak at the SETI (Search for Extraterrestrial Intelligence) Institute in Mountain View, California.

"Because the public is deeply marinated in the idea of aliens that are very much like us, it would be surprising to find AI rather than biological aliens," says Shostak. "But once bio-intelligence gets to the point where it can make a transmitter that's detectable by somebody's SETI experiment, then [that civilization] is within a few centuries of achieving artificial intelligence."

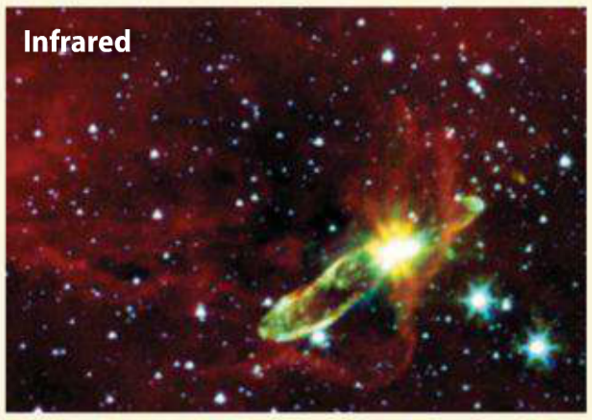
Bok globules could lure an expanding AI civilization with the promise of nearly unlimited energy and an extremely cold operating environment. The idea is that proximity to a hot protostar could provide lots of energy to AI machinery. The machinery's computational brain could face away from the star, however, taking full advantage of the globule's frigid temperatures.

Yale University astronomer Hector Arce says that even if super-advanced AI were perched in a cloaked corner of a nearby Bok globule, the machines likely still would use the radio part of the spectrum for communicating, both among themselves and with others outside these dense clouds.

Shostak says that in the process of searching for other machines, AI could be sending a low-powered but detectable radio ping our way. If so, looking for AI embedded in Bok globules also might make sense. As Shostak puts it, "The real intelligence in the cosmos may not be protoplasmic." — *B. D.*

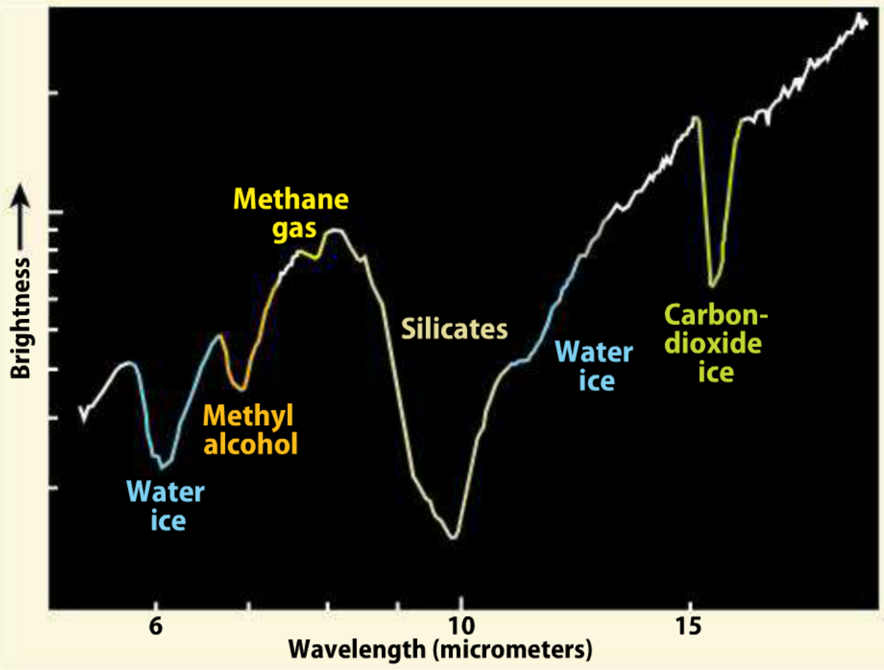
What happens when we detect alien life? Watch for **Seth Shostak's** article **NEXT MONTH** in our **May issue!**

Birth of a protostar?



Herbig-Haro 46/47 lies mostly hidden within this dusty Bok globule when viewed at visible wavelengths. Astronomers had long thought Boks could produce stars, but their thick clouds of dust effectively cloaked the process. Digitized Sky Survey

Near-infrared light penetrates the Bok globule and reveals a jet of molecular gas surrounding the protostar Herbig-Haro 46/47. The Spitzer Space Telescope captured both the embryonic star and its twin-sided jet. NASA/JPL-Caltech/A. Noriega-Crespo (SSC/Caltech)/H. Kline (JPL)



◀ **A spectrum** of Herbig-Haro 46/47 reveals a rich panoply of molecular species in a frigid environment. Note the ices of water and carbon dioxide along with silicate (rocky) material. *Astronomy*: Roen Kelly, after NASA/JPL-Caltech/A. Noriega-Crespo (SSC/Caltech)/H. Kline (JPL)

Nebula (M8) and singled out the dark nebulae Barnard 68, 69, 70, and 255.

Of all the Bok globules, Barnard 68 (B68) in the constellation Ophiuchus arguably has been studied more than any other. Somewhere between 100,000 and 1,000,000 years old, B68 lies at the edge of the elongated Pipe Nebula, from which it likely originated. B68 lies some 300 to 400 light-years from Earth and shows up readily through amateur telescopes from most of the world.

At first glance, B68 appears to be in a tenuous balance between the inward pull of gravity and the outward push of thermal pressure generated by radiation that the cloud absorbs. At a temperature of only 10 kelvins, it's some five times colder than uncloaked regions of the interstellar medium. But Williams says that even at such low temperatures, its gas can produce enough thermal resistance to offset gravity.

Although this globule looks inert at first glance, detailed observations hint at activity within its dark interior. "We think B68 is vibrating like the surface of a drum because it's been hit by something," says Charles Lada, an astrophysicist at the Harvard-Smithsonian Center for Astrophysics. "We see that it's oscillating like a beating heart. We don't know if these oscillations are stable or will lead to a collapse."

In the infrared part of the electromagnetic spectrum, B68 looks like it's in equilibrium. At the submillimeter wavelengths where it begins to radiate, however, it looks like it might be collapsing. B68 is denser toward the center than on the edge, which suggests that it is slowly on its way to making a star, says astrochemist Edwin Bergin from the University of Michigan in Ann Arbor. In 100,000 years, what we now know as B68 likely will be a low-mass red-dwarf star with a bit of dust around it.

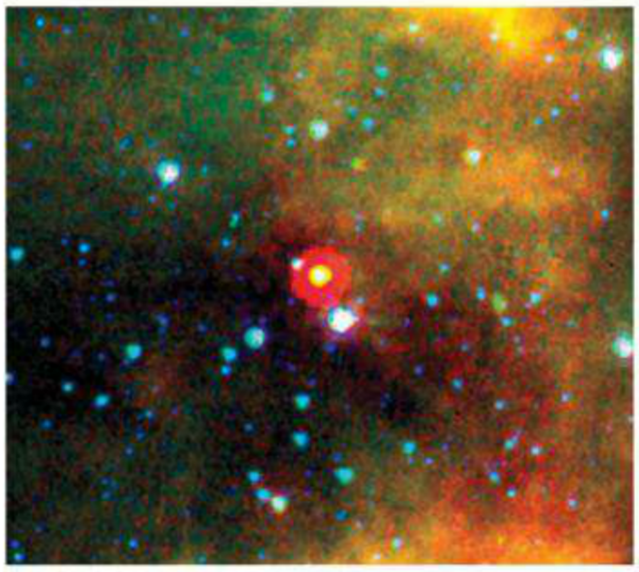
The Big Dog's globule

Other Boks appear to be further along the path to stardom. Ciardi already has observed at least five young stellar objects in CB 54, a globule located near the galactic plane and some 3,500 light-years away in the constellation Canis Major. "Two infrared sources inside CB 54 caught my attention as a possible site of multiple star formation," says Ciardi. "Originally, it was thought that Bok globules would only have a single star and that was it, but multiple star formation may be fairly common."

Even so, none of this appears to happen overnight. Even the densest Bok globules may take a few million years before they start to contract and form stars. And Boks do not collapse as a whole; instead, regions closest to their centers condense first.

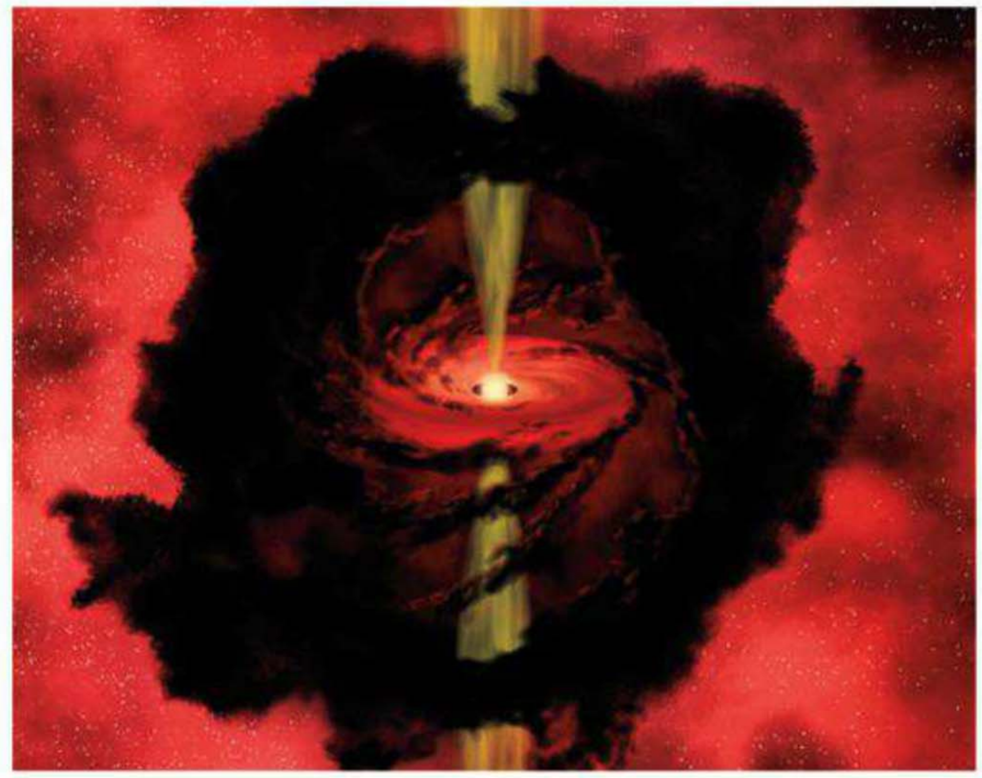
The first stage of stellar birth is a so-called hydrostatic core, in which the outward push of heated gas in a globule balances the inward pull of gravity. Gravitational heating within these structures can warm the cores to a couple of thousand kelvins. That's hot enough for the globule's molecular hydrogen to start dissociating into individual hydrogen atoms. This dissociation causes gas in the core to lose its ability to efficiently cool — a necessary step for the onset of star formation. The resulting heat also makes the globule even more gravitationally unstable.

Astronomers think that once a globule gets to the hydrostatic state, gravity eventually will win out, a protostar will form, and ultimately nuclear fusion will begin. "Understanding how stars and planets formed are two very coupled scientific endeavors," says Ciardi. "Can we really expect an Earth-like planet around a G star [the same class as the Sun] to be a very common event? Understanding the distribution of star masses can help us put our Sun and our solar system in context."



A protostar (center) peers out from the dark confines of Bok globule LDN 1014 in this near-infrared photo. NASA/JPL-Caltech/N. Evans (Univ. of Texas at Austin)

A cold dark cloud of molecular gas and dust blocks visible light from the surrounding reflection nebula NGC 1999. The nebula scatters and reflects light from the massive star V380 Orionis. NASA/ESA/Hubble Heritage Team (STScI/AURA)



A protostar develops inside a Bok globule in this artist's conception. Astronomers think low-mass stars (like the Sun) can form inside these globules, although many more form in clusters. NASA/JPL-Caltech/R. Hurt (SSC)

On the road to biology

It's not clear whether globules are better than star clusters at producing molecules that could prove important for life. Even so, there's no question that the globules are chemically rich environments that could be astrobiologically important. And without their prodigious amounts of dust, which facilitate the formation of molecular hydrogen and subsequently water, planets like Earth might lack a large part of their oceans.

Researchers are just beginning to reach the observational sensitivity they need to investigate globule chemistry more fully. They know that gas inside these globules freezes onto dust grains, a process not unlike a person's breath freezing as it hits a cold window. Interstellar ultraviolet (UV) radiation and cosmic rays then power chemical reactions on the globule's icy dust-grain surfaces.

The globules are chemically rich environments that could be astrobiologically important.

"UV radiation sunburns the surface of microscopic icy [dust] grains," says Max Bernstein, an astrochemist at NASA Headquarters in Washington, D. C. "By breaking the molecules in these ice grains into pieces, they later come back together in new ways, making new compounds. The Astrochemistry Lab at NASA's Ames Research Center [in Moffett Field, California] is one of the few places on Earth where we can reproduce this process."

The lab already has produced compounds that are both the building blocks of proteins and cell membranes. However, Bergin says that it's still hard to know what happens before a Bok globule gives birth to a protostar. That's because the chemical complexities of its icy grains don't get revealed until nearby stars evaporate the grains. Bergin also says that astronomers still don't have the observational sensitivity they need to detect the really complex molecules that might exist in dust-grain ices.

Space-based observatories like Spitzer and Herschel have identified several other fundamental molecules in infrared spectra of globules, including methanol, carbon dioxide, and ammonia. The more complex chemistry researchers expect remains hidden on the dust grains themselves.

That could change before long. The Atacama Large Millimeter/submillimeter Array (ALMA) in Chile, which already has some two dozen antennas in place, should help scientists detect more complex molecules on the surface of the globules' dust grains. ALMA also will help astronomers better understand the physics and chemistry of collapsing protostellar cores in Bok globules that do form stars. Specifically, the array will let researchers study emission from both dust particles and molecules as the globules heat up.

The submillimeter part of the spectrum reveals radiation at lower energies and longer wavelengths. The globules' dense molecular cores start to emit at this energy, explains Williams, and what appears dark at higher energies becomes bright.

"The infrared is more often used for identifying pieces of molecules," says Bernstein. "ALMA, on the other hand, will be looking in a wavelength range that corresponds to whole molecule motions and thus is better for identifying specific molecules."

The question then becomes what ALMA's future observations will reveal. Will the array show globules to be rich in complex organic molecules, or will it fail to find the sort of chemical complexity thought to spawn life? ALMA even may shed some light on whether Earth-like planets are more likely to form in open clusters or in Bok globules. Astronomers should have a good idea by the end of this decade.

Probably only a small percentage of Sun-like stars formed in Bok globules. But as Lada notes, if astronomers can't understand how a simple Bok globule turns into a single star, what hope do they have of ever understanding how giant molecular clouds form hundreds of star clusters?

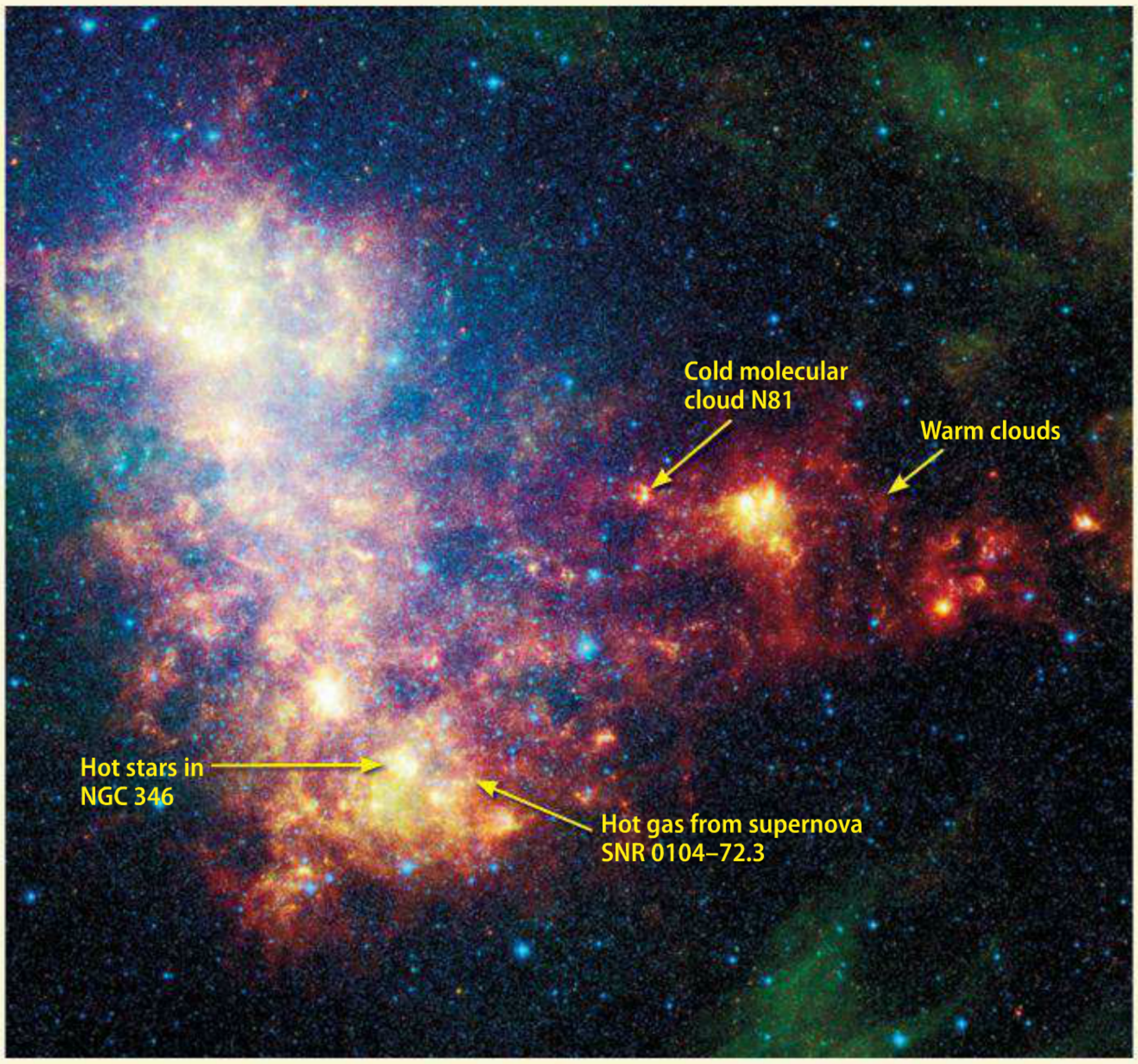
Astronomy's experts from around the globe answer your cosmic questions.

Radiating heat

Q: If space is only a few degrees above absolute zero, how can hot nebulae gases from exploded stars stay warm for a long time?
— **William Nopper,** Rochester, New York

A: What we think of as "heat" is the random motions of particles (or light photons). Transferring heat from one place to another takes time; how long depends on the density of the materials. Interstellar gases have low densities. If there were enough time (many times the age of the universe) and if the universe weren't expanding, eventually everything would cool to the same temperature. But the hot gas from, say, a supernova may take thousands of years to cool by radiating photons. This happens only when particles collide, and in the low densities of interstellar space, they don't collide often.

Starlight complicates things by keeping space from dropping to the temperature of the cosmic microwave background radiation that fills the universe. That temperature, about 3 kelvins (just above absolute zero), is the coldest anything can get without the aid of an outside process.



The Small Magellanic Cloud, like all galaxies, harbors many different sources of heat. It's these entities that keep the extremely hot gases from supernovae far above the temperature of the 3 kelvin background radiation. NASA/JPL-Caltech/K. Gordon (STScI)

In a typical galaxy, you can have molecular clouds at 10 K, where dust shields them from stellar radiation; warmer clouds at around 100 K that are heated by starlight and high-energy particles called cosmic rays; gases near hot stars at 10,000 K; and the gases resulting from supernovae that start out at 100 million K. The supernova gases cool relatively quickly in astronomical terms (thousands of years), but the ongoing heating processes keep the other objects at nearly the same temperatures. — **Stephen Reynolds,** North Carolina State University, Raleigh

OUR PLANET WOBBLES

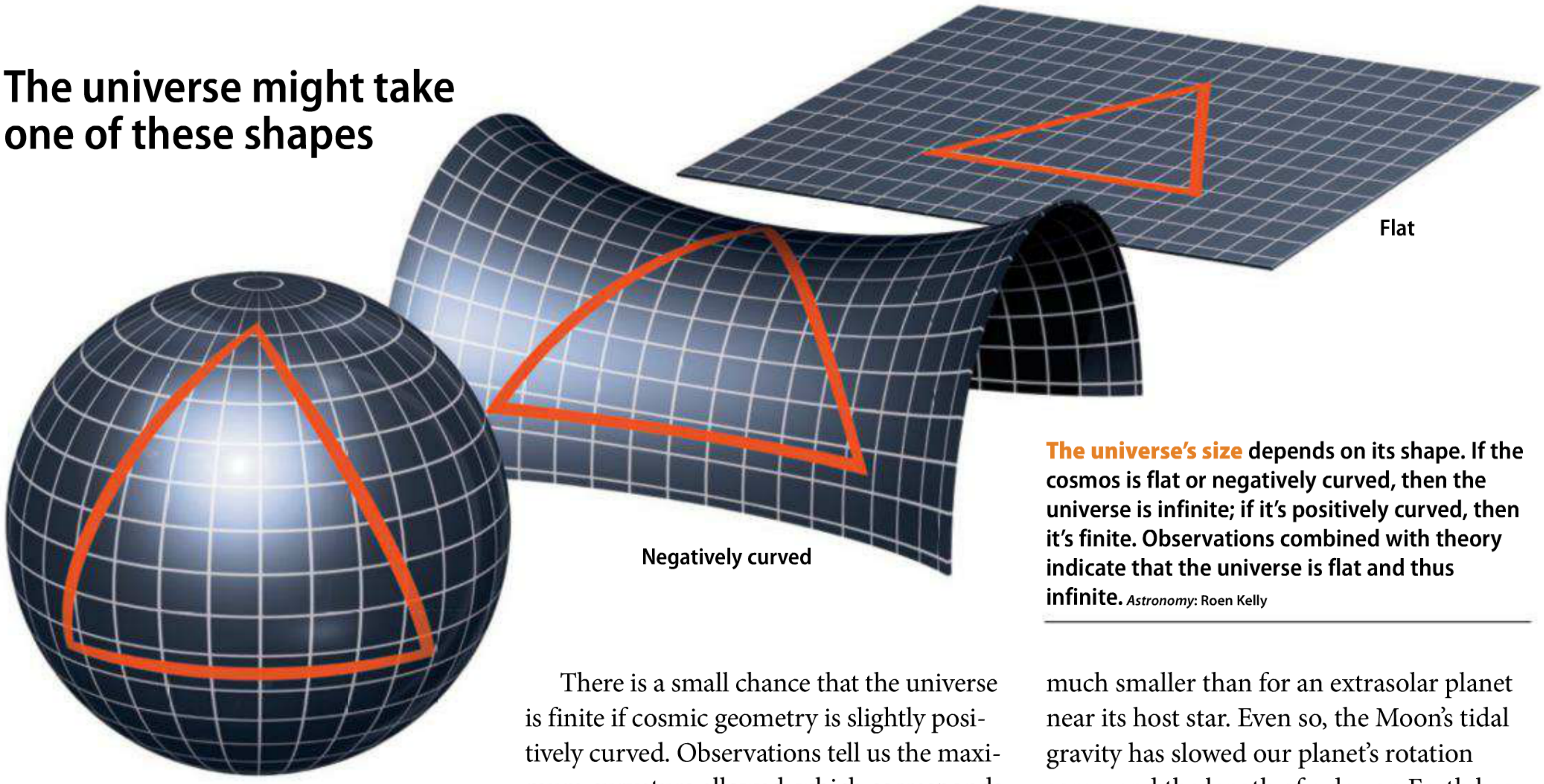
Q: Earth's axis is tilted 23½° with respect to the Earth-Sun plane. What factors contribute to its "wobble" over extended periods?
— **Robert Feingold,** Highlands Ranch, Colorado

A: The wobble of Earth's axis is called precession. While most of us are familiar with our planet's primary motions — rotation and revolution — few are aware of precession. This characteristic is vividly demonstrated by a spinning top or gyroscope whose tilted axis of rotation gyrates in a circular motion, sweeping out a cone-shaped area in the process.

You can cause a top or gyroscope to precess by gently tapping it while it's spinning. **The "tap" that causes Earth's axis to precess is gravity from the Sun and Moon and, to a much lesser extent, the planets. Gravity alone, however, won't do the trick. Earth has a slight equatorial bulge, and it's this bulge that gets the gravitational tug.** In other words, if the planet were a perfect sphere, there would be no precession.

While a top or gyroscope might precess several times each second, a single precession of Earth's axis takes nearly 26,000 years. The effects — changes in our "pole" stars, a shift in the celestial coordinates of right ascension and declination, and a westward drift of the solstices and equinoxes — are so gradual that most changes take decades to notice. No wonder precession is one of Earth's "unknown" motions.
— **Glenn Chaple,** Contributing Editor

The universe might take one of these shapes



The universe's size depends on its shape. If the cosmos is flat or negatively curved, then the universe is infinite; if it's positively curved, then it's finite. Observations combined with theory indicate that the universe is flat and thus infinite. *Astronomy*: Roen Kelly

COSMIC SHAPE AND SIZE

Q: Is the universe infinite or finite? Or is it so close to infinite that for all practical purposes it is?
— **Kyle Casteel,** Mooresville, Indiana

A: The universe's geometry determines whether the cosmos is spatially finite or infinite. The geometry could be flat, open (meaning negatively curved), or closed (meaning positively curved). In two dimensions, you can represent these geometries by a sheet of paper, the surface of a saddle, and the surface of a ball, respectively. In three spatial dimensions, however, they are a bit harder to visualize, but even in 3-D, angles in a triangle sum to 180° in a flat case, less than 180° in the open case, and more than 180° in the closed case.

The universe is finite if it is positively curved and infinite if it is negatively curved or flat.

Fortunately, cosmology experiments can measure cosmic geometry. In particular, the sizes of the hot and cold spots in the cosmic microwave background left over from the early universe are sensitive to the geometry of the universe. The spots appear bigger in positively curved space and smaller in negatively curved space. Measurements made over the past decade indicate that the universe is very nearly flat. (In fact, cosmic geometry is most likely exactly flat, since this is precisely what inflationary theory predicts.)

There is a small chance that the universe is finite if cosmic geometry is slightly positively curved. Observations tell us the maximum curvature allowed, which corresponds to the smallest size the universe can be. This lower bound implies that the cosmos is at least about 300 billion light-years across, which is a lot larger than how far we can (in principle) observe — which is about 50 billion light-years. **Observations combined with the spectacularly successful inflationary theory make it likely that the universe actually is infinite, and not just for practical purposes.** — **Dragan Huterer,** University of Michigan, Ann Arbor

PLANETARY DYNAMICS

Q: What causes a planet to be tidally locked as opposed to rotating freely? — **Jessica Merino,** Simi Valley, California

A: If a planet orbits extremely close to a star (as many extrasolar planets do), **the star's gravity stretches the planet into a shape called a prolate spheroid with a tidal bulge** that somewhat resembles a football. (The Sun's tidal distortions make tides in Earth's oceans.) The mass in that tidal bulge feels the gravitational pull of the host star, which tries to keep the bulge pointed toward the star. **For extrasolar planets very close to their host stars — about one-tenth Mercury's distance from the Sun — this gravitational pull eventually tidally locks the rotation,** and the length of the planet's day ends up equal to the length of its year.

The Sun and Moon's tidal gravity also try to slow Earth's rotation, but their effects are much smaller than for an extrasolar planet near its host star. Even so, the Moon's tidal gravity has slowed our planet's rotation some, and the length of a day on Earth has probably increased by about two hours over the past 620 million years. — **Brian Jackson,** Carnegie Department of Terrestrial Magnetism, Washington, D.C.

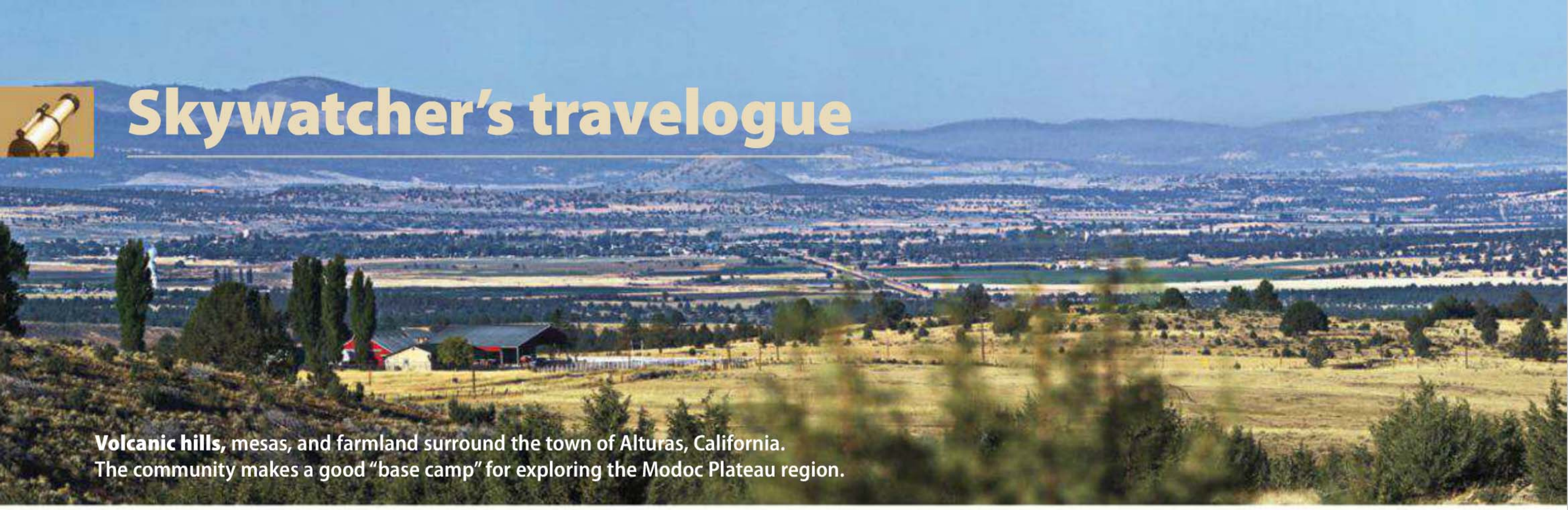
WHAT'S IN A NAME?

Q: I've seen *Astronomy* magazine label M33 as the Pinwheel Galaxy, but I thought M101 was the Pinwheel Galaxy and M33 was the Triangulum Galaxy. Which is correct?
— **Jim McCormick,** Victor, Idaho

A: Actually, M101 in Ursa Major has no common name (a real shame), although recently observers have begun to label it the Pinwheel Galaxy. **M33 is the one true Pinwheel Galaxy, however.** The name originated long before many of today's astroimagers were able to capture M101 so well. M33's name comes from a time when most observers were visual only.

People likely call M101 the name already taken by M33 because it looks like a pinwheel. There are also a lot of "whirlpool" and "needle" galaxy nicknames out there, but only one true Whirlpool Galaxy (M51) and Needle Galaxy (NGC 4565).
— **Michael E. Bakich,** Senior Editor

Send your questions via email to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.



Volcanic hills, mesas, and farmland surround the town of Alturas, California. The community makes a good "base camp" for exploring the Modoc Plateau region.

The Modoc Plateau beckons amateur astronomers

This California location has beautiful scenery, lots of amenities, and spectacular dark skies.

by Tony Hallas

The Modoc Plateau region lies in the extreme northeastern corner of California (with parts in Oregon and Nevada). The area, which sits about 5,000 feet (1.5 kilometers) above sea level, features volcanic lava flows and cinder cones 25 million years old. I rate it as one of California's undiscovered gems and, more importantly for amateur astronomers, one of the darkest places in the United States.

Three out of three

A site needs three things to be truly dark: no air pollution, no light pollution, and an altitude high enough to be mostly free of naturally occurring aerosols (mainly dust, humidity, and volcanic ash). The Modoc Plateau has all three. Virtually nothing lies west of it until you get to the Pacific Ocean. Human activity on the plateau is mainly cattle-raising and farming.

The best way to access this area is to head 172 miles (277 kilometers) north on U.S. Highway 395 from Reno, Nevada, a drive that takes slightly less than three hours. You'll arrive at the main town in the area, Alturas, which has a population near 3,000. Here, you can find several good motels and a few places to eat, including one of my favorites, the Brass Rail, a famous Basque-style restaurant. If you're an amateur astronomer like me, you'll probably use Alturas as a base camp and drive out into the countryside with your setup to enjoy the incredible skies.

I rate it as one of California's undiscovered gems and, more importantly, one of the darkest places in the United States.

Heaven on Earth

As nice as the Alturas area is, I can offer you an even juicier alternative. Just drive 18.4 miles (29.6km) south to a tiny dot on the map called Likely. Turn off Highway 395, go about half a mile, and there, in the absolute middle of nowhere, you will find Likely Place RV Resort and Golf Course.

My wife, Daphne, and I discovered it by accident some years ago when we were exploring the area. A lake that had looked promising on Google Earth turned out to be a crater lake surrounded by trees. It was late in the day, so we headed back from where we came and in the dark pulled onto a knoll to spend the night.

The next morning, we discovered we were right next to the entrance of what looked like a fancy RV resort. Imagine our surprise when we found that this place offers clean bathrooms, hot showers, a nice and reasonably priced restaurant, and — miracle of miracles — a challenging 18-hole golf course, all under the darkest skies I've seen in California. The golf course spreads out over a vast tract of land and throughout delivers expansive views of the surrounding countryside, including the Warner Mountains.

At night, the resort has lights, but if you ask permission of the owners, they will allow you to turn most of them off. For sky viewing, you can either set up in a well-maintained grassy field or drive to the top of a hill directly behind it for a 360° view. It's worth the walk up there to see the Milky Way stretch from horizon to horizon in the summer.

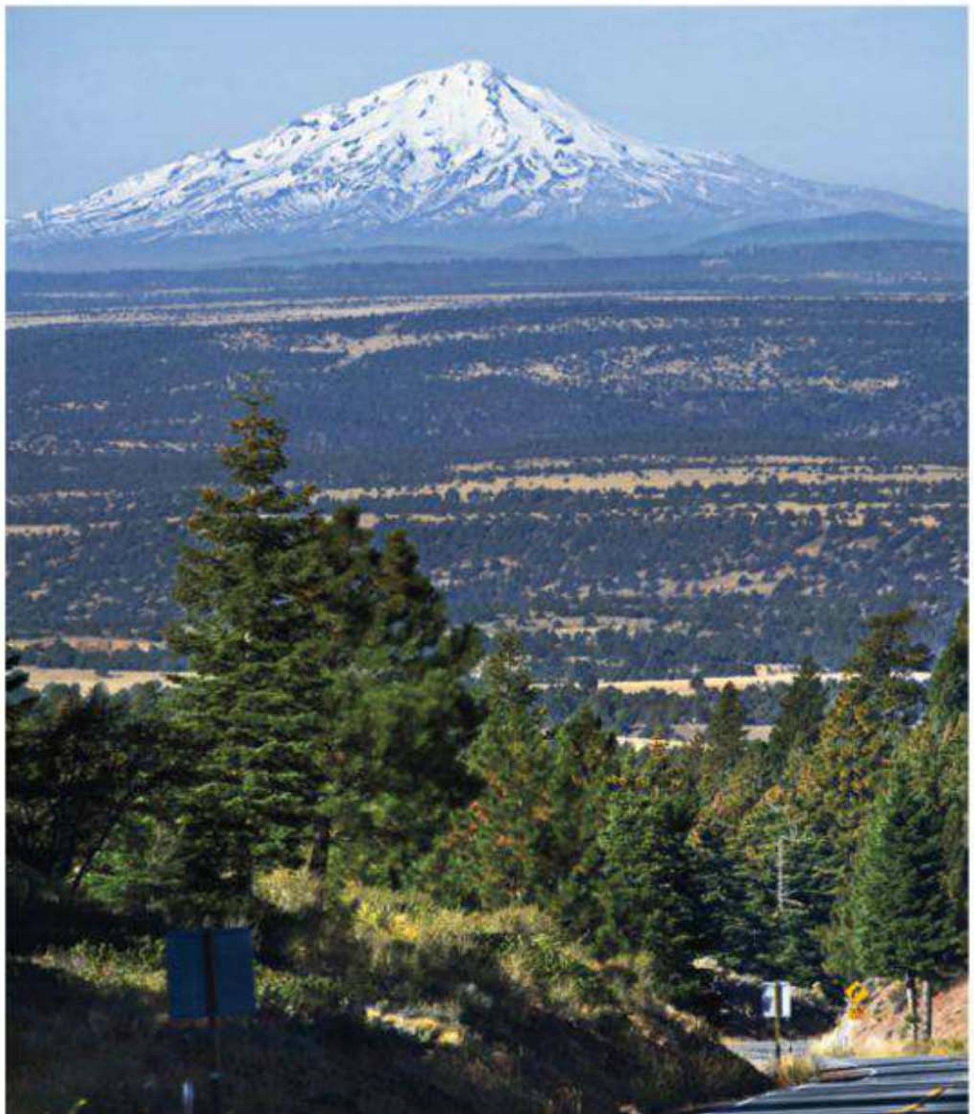
A few terrestrial lights here and there come from farmhouses scattered throughout the valley, but they do nothing to the sky. Still, if you want absolute black, a

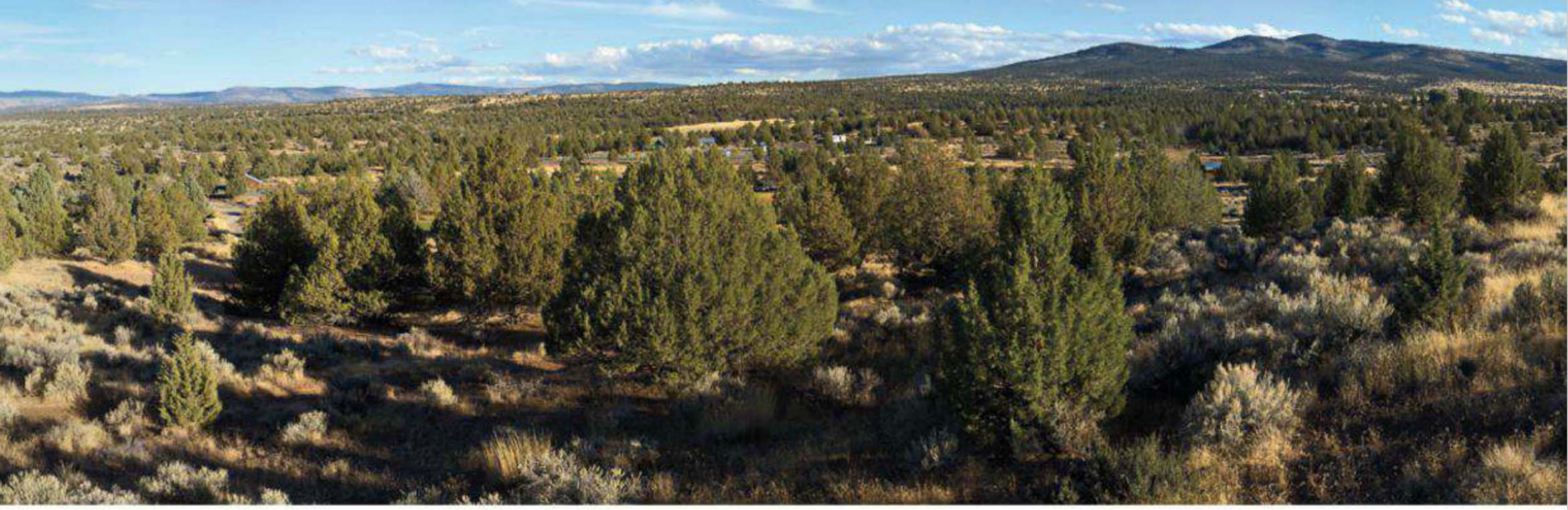
Tony Hallas *is an* Astronomy *contributing editor and an avid astroimager. Check out his column each month.*

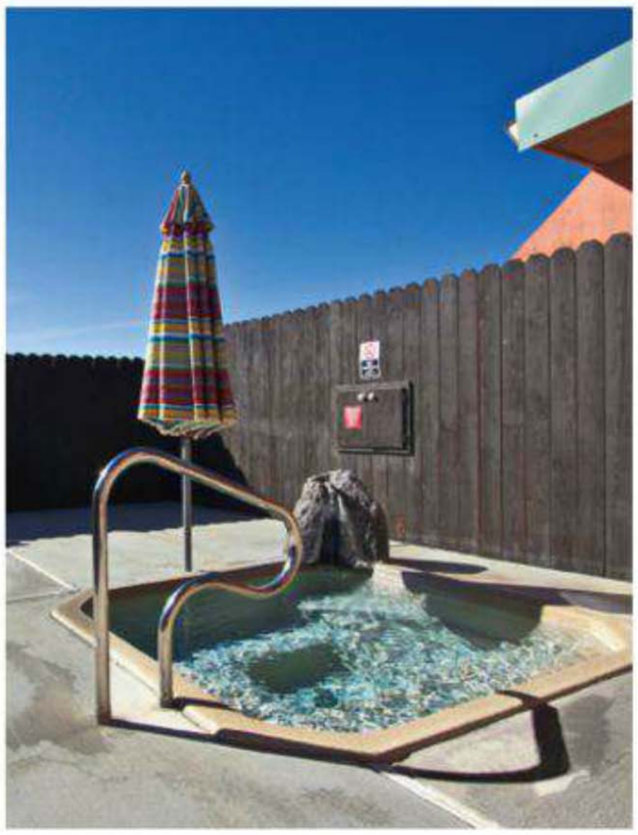
The Stellarvue Dark Sky Star Party occurs each year near a New Moon at Likely Place RV Resort on the Modoc Plateau. Visual observers and astroimagers alike experience one of the darkest sites in the United States. All photos: Tony Hallas

▲ **The Modoc Plateau** lies in the northeastern corner of California near that state's borders with Oregon and Nevada. *Astronomy*: Roen Kelly

▶ **On a clear day,** you can see Mount Shasta. The author took this image through a telephoto lens. Mount Shasta lies 80 miles (129km) away as the crow flies, a testament to the clean air surrounding Modoc Plateau.







Likely Place RV Resort (small white building above center) sits in the absolute middle of nowhere. It offers access to some of the darkest skies in the United States, modern facilities, a grassy area for observing or imaging, and an 18-hole golf course.

▲ **You'll find Surprise Valley Hot Springs** just east of the small town of Cedarville. This resort lies on top of natural hot springs. Most of the rooms have an outdoor hottub.

▼ **Likely Place Golf Course** sits under an ultra-dark sky. It offers expansive daytime views of the Modoc Plateau and the Warner Mountains, which are part of the region.

20-minute drive on a dirt road will take you to places so dark, they're spooky.

Social astronomy

A few years ago, we dragged Vic Maris, founder of Stellarvue Telescopes, to Likely Place after we attended the Golden State Star Party. Maris took one look at the resort and the annual Stellarvue Dark Sky Star Party was born. Registration for the star party sells out quickly each year because Maris can only take as many people as the restaurant can feed in one sitting.

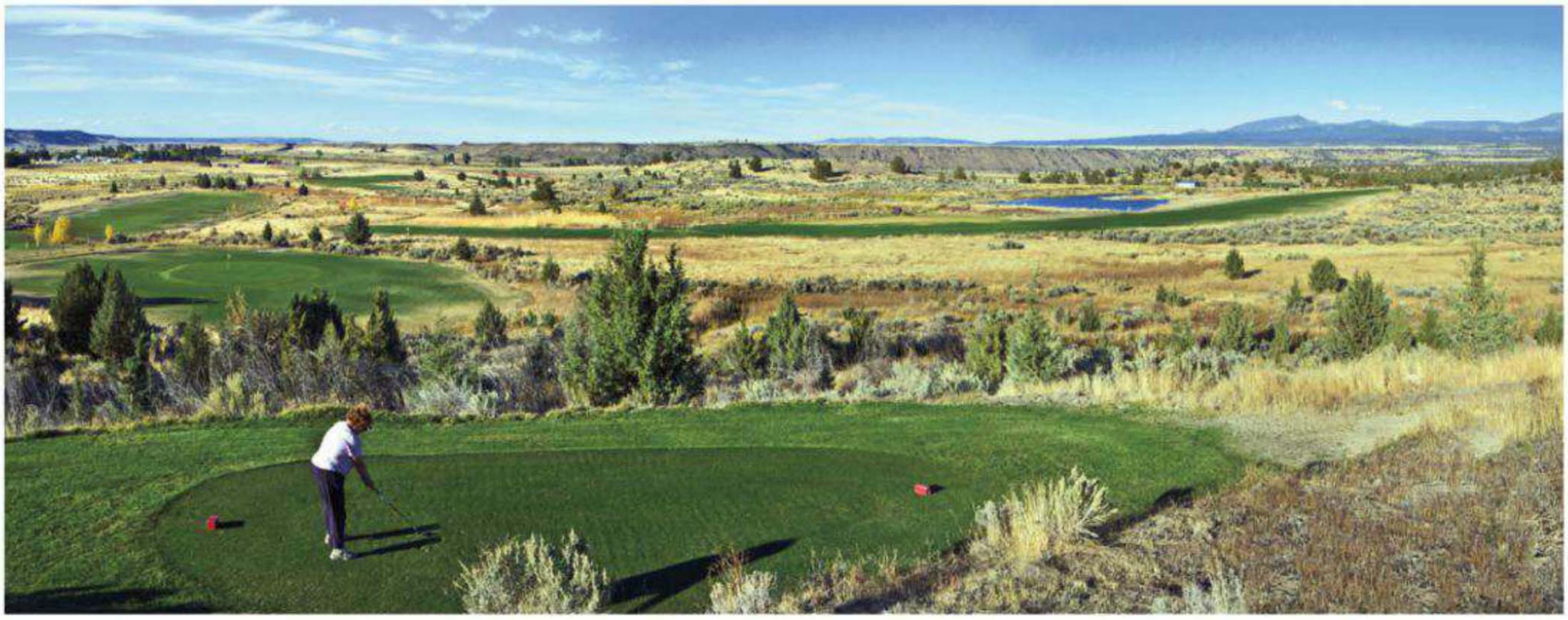
If more people knew about Likely Place, it would host many star parties. One caveat: I have found that during the late summer, you run the risk of monsoonal storms and smoke from forest fires, so early summer is the best time to visit.

For the hardiest observers, the resort allows camping through the winter with electricity and hot showers still provided. It can get mighty cold, but the sky remains incredibly clear. Daphne and I are planning a midwinter expedition this year with some new observing equipment if we see a string of clear nights in the forecast.

What, there's more?

For those of you who like a bit of sightseeing with your astronomy, you can visit numerous lakes, a world-class wildlife area to view migrating birds, and Lava Beds National Monument. The latter, 90 miles (145km) away near Tulelake, is a maze of volcanic tubes of different sizes and lengths that you can hike through.

The best ones are internally illuminated, and all have interesting information posted. Also, an observation tower and a small campground are on location. In one of the giant lava tubes, you can climb down to an ice cave via what seems like an endless ladder in pitch-black darkness. My friends, this is not for the faint of heart or people who suffer from vertigo. As you descend,



To create this composite image, the author superimposed a photograph of migrating snow geese that he took north of Alturas over a shot of the Full Moon (which he also took). This image won highest marks in a California photo competition.

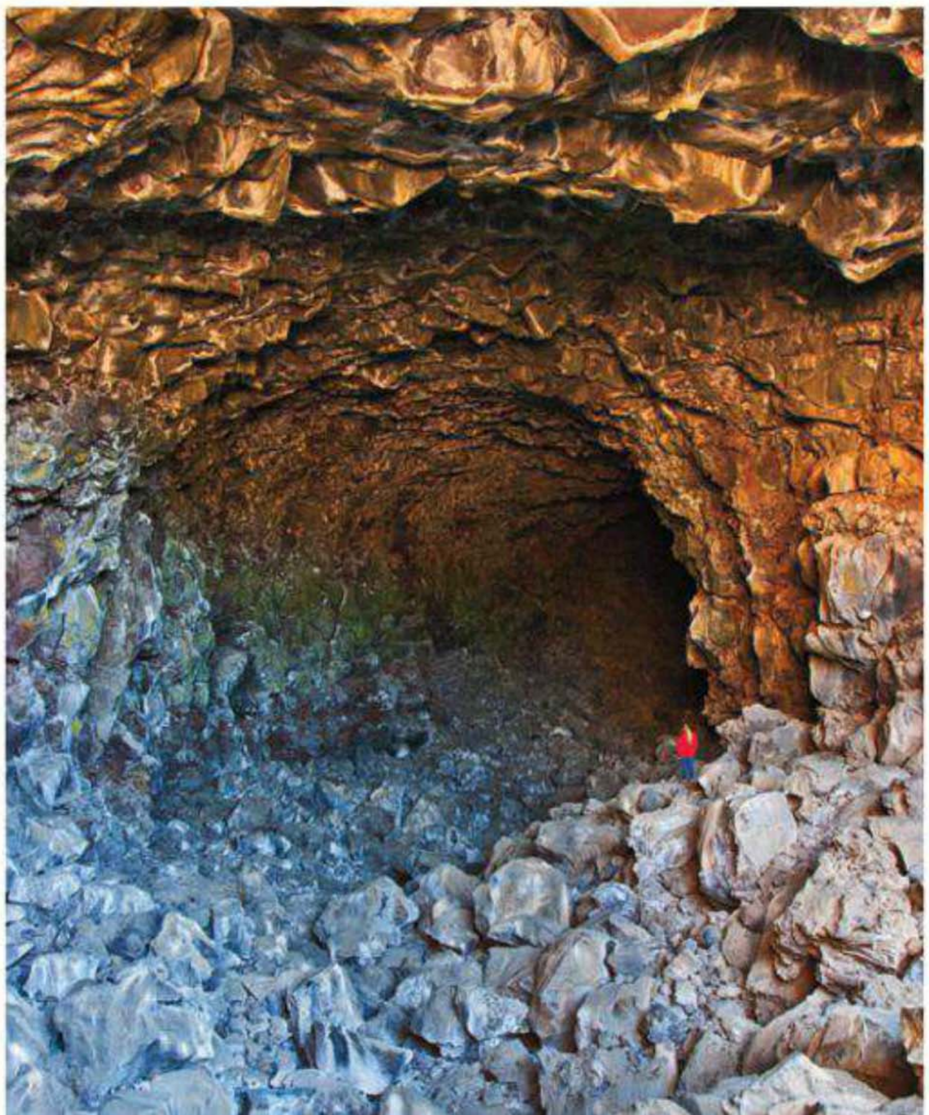
you can feel the temperature plummet even if it's a warm day outside. Take my advice and wear comfortable walking shoes.

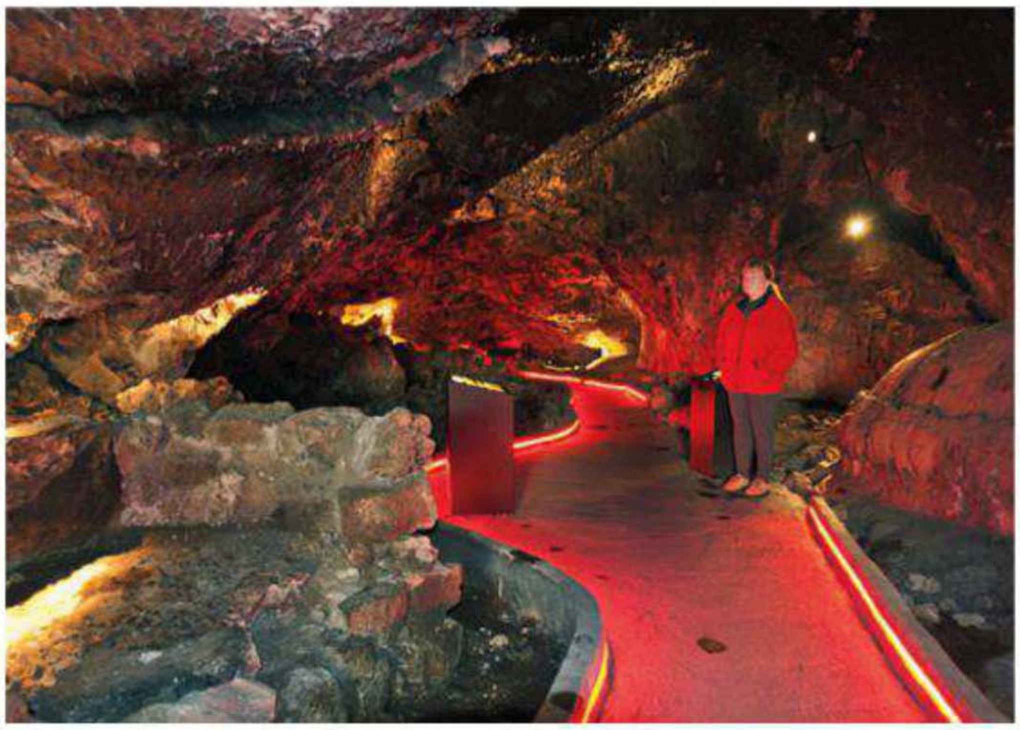
Driving 20 miles (32km) east from Alturas brings you to the small community of Cedarville. Just a few miles farther east and you'll be in Nevada. Years ago, some enterprising individuals opened a casino and brothel just across the border, but the wives of Cedarville banded together and burned it down. Welcome to the Wild West!

Five miles east of Cedarville, you'll find Surprise Valley Hot Springs, a fantastic resort built over natural hot springs where most rooms feature an outdoor hottub. Here, you can drink a glass of wine and gaze at the Milky Way while warm mineral water washes away all your cares and stress. I recommend you get a reservation if you're headed there on a weekend because this is a popular place with California's "let's do something unique" crowd.

Check your schedule and go!

The Modoc Plateau undoubtedly has more hidden gems that even we haven't discovered. If you're an amateur astronomer who has attended other star parties, Likely Place offers similarly dark skies without the dust. It also features a staff willing to cater to our hobby, clean bathrooms and showers, a great little restaurant, and an 18-hole golf course. Frankly, Daphne and I are now spoiled rotten.





▲ **Daphne Hallas,** the author's wife, stands in one of the lava tubes at Lava Beds National Monument, which lies 90 miles (145km) northwest of Likely.

◀ **One can only imagine** the volume of lava that poured through this giant lava tube. At its end, a long vertical shaft with a ladder that you can climb down — if you have the nerve — leads to an ice cave.

Use Facebook to get more out of your hobby

Photo illustration by © Scanrail | Dreamstime.com and Alison Mackey. Space images: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

These nine tips will help you get the most out of this social network, connecting you to astroimagers, astronomy clubs around the world, and even space missions. **by Michael E. Bakich**

What if I told you that technology has reached a point where we can watch a spacecraft launch, share our best celestial images, or attend an astronomy club meeting without ever leaving home — all from a single website called Facebook? Because it's the second-most popular of all Internet sites (only Google tops it), you're probably already familiar with some of Facebook's features. But this vast collection of individuals, groups, images, videos, and events has a tremendous amount to offer hobbyists who love astronomy.

Michael E. Bakich *is an* Astronomy *senior editor and author of* 1,001 Celestial Wonders to See Before You Die *(Springer, 2010).*

I'm a big fan of 19th-century astronomy. That's when an individual really could make a difference by discovering asteroids, comets, or even planets just by putting eye to eyepiece. The drawback was that early amateur astronomers all were solo enterprises. Precious little interaction occurred.

Fast-forward to the 20th century and the rise of astronomy clubs. Then (and it still continues today), like-minded individuals could get together for monthly meetings, observing sessions, and even national conventions. But what if you belong to a small club and you're the only one interested in imaging? Or maybe you joined a big club but find yourself the sole member who enjoys observing faint, obscure galaxy clusters from a remote site. For you, it may as well be the 19th century.

Enter Facebook. In only eight years since its creators launched it, this social networking site has collected what's best about astronomy on the Internet. It now offers this wealth of information to astronomers of all levels for free.

Tips for Facebook astronomers

To label Facebook vast is akin to calling the universe "kind of big." Newcomers to the website, therefore, might feel lost. Here are nine things I've learned that can make your Facebook experience a little easier.

1 **Don't ignore your "Home" page.** Access it by clicking just to the right of your name at the top of your Facebook page, or just click the Facebook logo in the upper left corner. Here's where you'll find "stories"

posted by the friends you add. Many of mine include new pictures they've posted.

2 Whenever you search for someone or something, narrow down your criteria by selecting "People," "Pages," "Groups," or another category from the menu at the upper left of the search page. This will save you time you would otherwise spend wading through individual names when you're looking for a group to join.

3 Expand your astronomical horizon by following more than just other amateur astronomers. For example, you can see what's going on with current space missions, universities involved in astronomical research, individual astronomers, equipment manufacturers, and other publications.

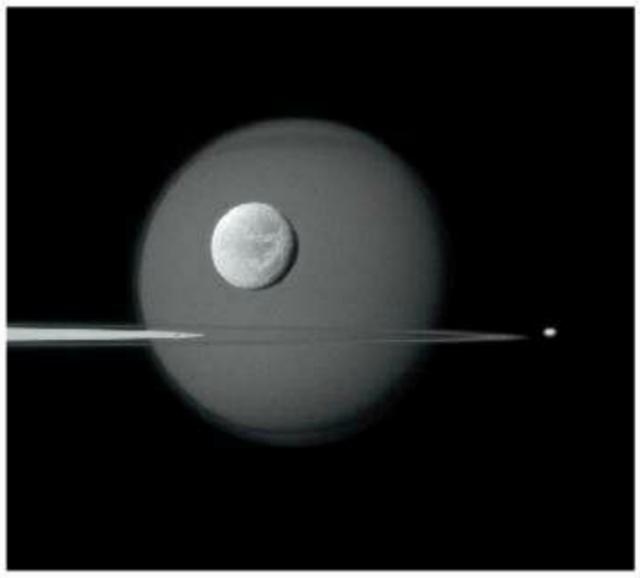
Facebook has made it easy to give positive feedback or to connect with something you care about. Just "Like" it. This sends the content to your friends' News feeds.

4 Take a few moments to familiarize yourself with any group you plan on joining. If you don't, you may land in an astroimaging group with more than 6,000 members who mainly speak Greek!

5 To generate the most feedback from your "Update Status" box (the one labeled "What's on your mind?"), follow your statement with a question. I recently posted, "On this date (1 November) in 1520, Ferdinand Magellan navigated the strait that now bears his name. The Magellanic Clouds also bear his name. For those of you who have seen them, what were your impressions?" I received a bunch of interesting comments, several of which I then commented on.

6 With regard to responses, the time of day matters greatly. Let's say, for example, that all your friends live in the continental United States. If you post messages and updates at 10 A.M. CST on a weekday, odds are that most of your friends will be at work. Replies will probably begin arriving in the early evening. Post whenever; just temper your expectations as to when comments will come in.

7 Pictures are worth a thousand words. Try posting a small photo album or three that relate to astronomy. Facebook has made it easy, and then you can just watch the comments roll in. One album might contain images that you've taken through a telescope. Don't worry if you're a beginner — you'll be surprised at how helpful people can be. Another can show pictures of places you've visited. Observatories, museums, and historical sites top the list. A third can chronicle events like club meetings or star parties in you've attended.



The Astronomy Picture of the Day Facebook page offers a different amazing celestial image each day. The group encourages members to "Like" or comment on each image. The Cassini spacecraft orbiting Saturn took this close-up view of the ringed planet and several of its moons. NASA/JPL-Caltech/Space Science Institute

8 If you want your Facebook uploads to have the maximum reach, then opt for a "page" rather than — or in addition to — a "profile." The website limits the amount of "friends" (people you can communicate with via public or private messages or through the website's "chat" feature) one user's profile can have to 5,000. (If you think you could never have that many friends, you might be in for a surprise.) But pages have "followers," and Facebook imposes no ceiling on their number.

9 Finally, for others, keep your page or profile updated and active. And for yourself, keep it fun. Remember, you don't have to upload a gigabyte of pictures each day. That's a lot of stress and a quick way to burn out. I'll give you a positive example.

Did you know?

- **Facebook launched in February 2004.**
- **Facebook ranks as the second-most popular website on the Internet.**
- **Facebook now has more than 800 million active users.**
- **As of April 2010, 41.6 percent of the U.S. population had a Facebook account.**
- **Facebook reached 1 trillion page views in June 2011.**
- **Facebook paid $8.5 million for the domain name fb.com.**
- **By the summer of 2011, users had uploaded more than 100 billion photos requiring a storage capacity of some 2 petabytes. As of May 2009, 220 million new photos became part of Facebook each week.**
- **Facebook requires only that users are 13 years old and have an active email account.**

One of my friends, a longtime astroimager, joined Facebook recently. He had created more than 100 high-quality images he wanted to share and considered uploading them as two photo albums. But after chatting with a few of his friends (I may have been one of them), he decided to post only 10. Now, every two or three days, he uploads another. And with each new post, comments from others fill his screen. His method engages his friends, keeps his profile vibrant, and rewards his efforts.

Come join the party

Although the creators of Facebook probably weren't thinking "astronomy" at the start, the website now hosts millions of people with an interest in the subject. More to the point, many — call them "future friends" — who joined for the communal aspects will follow and respond to your passion for science. Within a month, I predict, you'll find yourself quite comfortable as Facebook's newest social astronomer.

You can begin at *Astronomy*

If you'd like to get a quick start on Facebook, log in and point your Internet browser to **www.facebook.com/AstronomyMagazine**. That's our page, which we update regularly. You can follow developments on both the science and hobby sides of astronomy by just clicking on the link included with each post. Some will lead to images, others to videos, and still more to news stories. If you like what you see, please click the "Like" button at the top of the page.

Andromeda • Antlia • Apus • Aquarius • Aquila • Ara • Aries • Auriga • Boötes • Caelum • Camelopardalis • Cancer • Canes Venatici • Canis Major • Canis Minor • Capricornus • Carina • Cassiopeia • Centaurus • Cepheus • Cetus • Chamaeleon • Circinus • Columba • Coma Berenices • Corona Australis • Corona Borealis • Corvus

How the **constellations** came to be

The starry figures that fill our sky result from more than 6,000 years of human imagination. **by Michael E. Bakich**

Today, we recognize 88 constellations. They cover the sky with no gaps or overlap. But it wasn't always this way. Throughout history, celestial mapmakers were free to populate the heavens with as many figures as their imaginations could create. How, then, did we arrive at our present-day star patterns?

Ancient people assigned names to star groups beginning at least 6,000 years ago. The most enduring constellations, however, trickled down through the ages to coalesce in Greece in the 4th century B.C.

From that point, some two millennia passed before the astronomical community made 88 regions of the sky "official." That act brought to a close seemingly endless revisions and left us with — at least in the short term — the beautiful and unchanging constellations we see each clear night.

Michael E. Bakich *is an* Astronomy *senior editor and author of* 1,001 Celestial Wonders to See Before You Die *(Springer, 2010).*

c. 3900 B.C. The Akkadians, who lived in present-day Iraq, refer to the zodiac as the Furrow of Heaven. **Taurus** is the preeminent zodiacal constellation from 4525 B.C. to 1875 B.C. because the Sun stands before its stars on the vernal equinox. The bust pictured shows Sargon the Great, Akkadian emperor in the 23rd century B.C.

Iraqi Directorate General of Antiquities

c. 1400 B.C. The earliest known inscriptions for Chinese star names appear on oracle bones — pieces of animal bone that early occultists used for divination. The tortoise plastron oracle bone pictured here dates from the Shang Dynasty (c. 1600 B.C.–c. 1050 B.C.).

BabelStone/Wikimedia Commons

c. 1200 B.C. The first Babylonian star catalog, known as the Three Stars Each text, appears in cuneiform. It divides the sky into zones where the Sun spent three consecutive months in each section.

c. 780 B.C. Greek poet Homer (pictured on this 50 drachmae coin) composes the *Iliad* and the *Odyssey*. He mentions five star patterns by name (the Clusterers [**the Pleiades**], the Bear [**Ursa Major**], **Orion**, the Ploughman [**Boötes**], and the Rainy-ones [**the Hyades**]), but references many others.

Anthony Ayiomamitis

c. 600 B.C. Thales of Miletus, Greece (now part of Turkey), defines **Ursa Minor the Bear Cub** and suggests its use for navigation. Rogelio Bernal Andreo

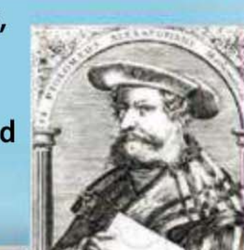
Before 433 B.C. The Chinese divide the zodiac into the Four Symbols — the Azure Dragon, the Black Tortoise, the White Tiger, and the Vermilion Bird. They subdivide each symbol sevenfold, creating the Twenty-eight Mansions. *Astronomy*: Roen Kelly

c. 350 B.C. The ancient Greeks refer to the apparent path of the Sun through the constellations as *zodiakos kyklos*, the "circle of animals."

c. 330 B.C. Greek astronomer Eudoxus of Cnidus creates a celestial globe on which he pictures the star figures usually referred to as the Greek traditional constellations. Unfortunately, none of his work survives.

c. 270 B.C. Greek poet Aratus, a native of the ancient city of Soli, now in Turkey, writes *Phaenomena*. The first half of this poem sets to verse a work by the same name by Eudoxus and includes 44 of his star figures.

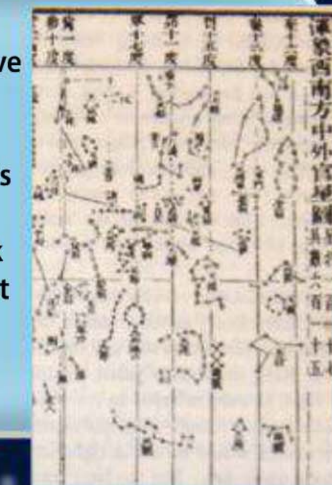
c. 150 B.C. Greek scholar Claudius Ptolemy (pictured) publishes *Almagest*, a treatise on mathematics and astronomy. In it, he mentions 48 star patterns, now considered the "original" constellations of the Greeks. Of these, only two — **Argo Navis** and **the Pleiades** — are no longer constellations. Wikimedia Commons



c. 350 *Constellātiō* ("set with stars") is a Late Latin word from this time. An astrological term, it described stars that influenced Earth. The definition of "constellation" as an area of sky around a stellar pattern dates to the middle of the 16th century.

extans • Taurus • Telescopium • Triangulum • Triangulum Australe • Tucana • Ursa Major • Ursa Minor • Vela • Virgo • Volans • Vulpecula •

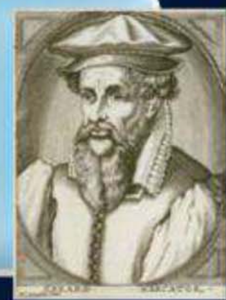
c. 1090
Chinese astronomer Su Song produces five woodcut charts of constellations and publishes them in his celestial atlas *Xinyi xiangfayao*. His work represents the oldest extant star maps in printed form. Wikimedia Commons



1503
Italian navigator Amerigo Vespucci is the first to depict the constellations of **Crux** and **Triangulum Australe** in a letter to Italian statesman Lorenzo de' Medici. Wikimedia Commons

1515
Albrecht Dürer, Johann Stabius, and Conrad Heinfogel create the first printed star maps in Europe — *Imagines coeli Septentrionales cum duodecim imaginibus zodiaci* and *Imagines coeli Meridionales*. The first centers on the north ecliptic pole and shows the 12 zodiacal constellations with numerous other figures in the northern sky. The south ecliptic pole is the center of the second map, which shows only 15 constellations.

1551
Dutch mapmaker Gerard Mercator introduces **Coma Berenices** on a celestial globe he designs. Wikimedia Commons



1592
The constellation **Columba the Dove** first appears on a celestial chart by Flemish mapmaker Petrus Plancius.

1595–7
Two Dutch navigators, Frederick de Houtman and Pieter Dirksz Keyser, create 11 southern constellations: **Apus**, **Chamaeleon**, **Dorado**, **Grus**, **Hydrus**, **Indus**, **Musca**, **Pavo**, **Phoenix**, **Tucana**, and **Volans**. Plancius shows these figures on a globe, which doesn't survive.

1603
German celestial cartographer Johannes Bayer publishes *Uranometria*, the first great star atlas. Although he invents no new constellations, this work stands out because in it Bayer first labels the brightest stars with Greek letters, a practice still followed today.

1690
The constellations **Canes Venatici**, **Lacerta**, **Leo Minor**, **Lynx**, **Scutum**, **Sextans**, and **Vulpecula** (pictured) first appear in German astronomer Johannes Hevelius' *Firmamentum Sobiescianum, sive Uranographia, totum Coelum Stellatum*. Linda Hall Library of Science, Engineering, and Technology

1756
French astronomer Nicolas Louis de Lacaille invents 14 new constellations in *Mémoires Académie Royale des Sciences*. He chooses figures that represent contemporary scientific equipment: **Antlia**, **Caelum**, **Circinus**, **Fornax**, **Horologium**, **Mensa**, **Microscopium**, **Norma**, **Octans**, **Pictor**, **Pyxis**, **Reticulum**, **Sculptor**, and **Telescopium**. He also divides **Argo Navis** into three distinct constellations, but doesn't picture them.

1764
The immense constellation **Argo Navis** appears for the first time pictured as three separate constellations on the star chart *Hémisphère Céleste Antarctique ou Austral* by French mapmaker Gilles Robert de Vaugondy. They are **Carina the Keel**, **Puppis the Stern**, and **Vela the Sail**.

1922
American astronomer Henry Norris Russell proposes a three-letter abbreviation for each constellation at the First General Assembly of the International Astronomical Union (IAU), held in Rome. We still use his three-letter versions. Astronomical Society of the Pacific

1928
A committee under the direction of Belgian astronomer Eugène Delporte presents a report to the IAU setting the official boundaries of the 88 constellations.

1930
Délimitations scientifique des constellations, the printed version of the 1928 IAU report, appears. Michael E. Bakich library

Today
Some stars find themselves in different groupings because of the new boundaries that Delporte's committee established. One such example is the magnitude 4.0 star 10 Ursae Majoris. English astronomer John Flamsteed cataloged that star as part of the Great Bear. Now, however, it lies squarely within the constellation **Lynx**. *Astronomy*: Richard Talcott and Roen Kelly

A+ View how stars orbit Sagittarius A* at www.Astronomy.com/toc.

...s • Crater • Crux • Cygnus • Delphinus • Dorado • Draco • Equuleus • Eridanus • Fornax • Gemini • Grus • Hercules • Horologium • Hydra • Hydrus • Indus • Lacerta • Leo • Leo Minor • Lepus • Libra • Lupus • Lynx • Lyra • Mensa • Microscopium • Monoceros • Musca • Norma • Octans • Ophiuchus • Orion • Pavo • Pegasus • Perseus • Phoenix • Pictor • Pisces • Piscis Austrinus • Puppis • Pyxis • Reticulum • Sagitta • Sagittarius • Scorpius • Sculptor • Scutum • Serpens • S...

Astronomy tests Orion's color video camera

The StarShoot Deep Space Video Camera displays celestial objects in real time and captures video frames. **by Chris Schur**

As a broadcast video engineer by profession, I was keenly interested in giving Orion's StarShoot Deep Space Video Camera a shakedown cruise. And as a longtime amateur astronomer who's played host at many public viewing sessions, I couldn't wait to target my favorite bright deep-sky and solar system subjects to bring their images up live on a high-resolution television monitor.

Finally, from an astroimager's standpoint, I was excited about the photographic capability of this camera. I knew I'd have a chance to produce some shots through it on a steady night.

What's in the box

Orion has produced a rugged camera in an all-metal housing. A C-to-CS mount adapter allows the use of standard ½-inch format lenses for wide-field imaging. For use on a telescope, a C-to-1¼" adapter permits the camera to fit any 1¼" focuser (or a 2" focuser with a 1¼" adapter).

To provide power, Orion includes an AC adapter and a 12-volt DC standard automobile accessory ("cigarette lighter") plug. Both connect to the "Power in" jack at the rear of the camera. For my use, the composite video output connected directly into the back of my television set using the long cable the company provided. Finally, Orion's Video Capture Device and software allowed me to use this camera as a webcam to acquire images of solar system objects.

Video mode at the telescope

As the twilight deepened to a dark navy blue, I pointed my homemade 12.5-inch Newtonian reflector at the 50-percent-illuminated Moon. I had connected the StarShoot camera to a 12-inch Sony monitor in my backyard observatory. When the camera powered up, the Moon's face bloomed in pure white from overexposure.

I changed the exposure mode from "Auto" to "Shutter" and was able to get a perfect exposure when I set the camera to 1⁄1,000-second. The Moon's image on the monitor displayed myriad craters and dark-toned maria. Delicate craterlets, tiny rilles, and miniature mountain shadows popped in and out of view as the seeing (the steadiness of the air above my site) varied. The best part about this system was that both my wife and I were able to see the image at the same time.

Because 1⁄1,000-second is the minimum exposure this camera shoots, if the Moon had been brighter, I would have needed to create a round diaphragm for my scope to cut its glare. Our natural satellite is so bright that even a 3-inch (76 millimeters) hole would have provided plenty of light. But it looked great at that exposure.

Likewise, the images I captured of Saturn did not disappoint. We viewed it flanked by two of its moons and a few field

The complete package features both AC and DC power adapters, output cables, a C-to-1¼" adapter, and Orion's Video Capture Device.

Orion's StarShoot Deep Space Video Camera employs a 0.5-inch Mintron color sensor with a 768x494 pixel array. Orion loaded the rear of its StarShoot camera with inputs, outputs, a power connector, and more. Equipment images: *Astronomy*: William Zuback

stars that clearly exhibited gold and blue colors. The planet stood low in the sky, however, so it was time to move on to what both of us really wanted to test: this product's performance on deep-sky objects.

Once I had centered the Ring Nebula (M57) in the camera's field of view, it was clearly visible but dim. By setting the software's "Sense Up" value to 128, the camera's gain increased, and after about 10 seconds the view stabilized to a pale-green gem with red-tinted edges surrounded by a sea of scintillating red-colored noise. And yes, the central star was right there for both of us to see without difficulty. I judge this an impressive feat for a mere 4-second video exposure.

The StarShoot Deep Space Video Camera's ability to show both faint objects and star colors will be a major boon to astronomy clubs hosting public star party events. I'm certain it will greatly increase the level of interest among the public.

Chris Schur *is a longtime amateur astronomer and imager who lives in Payson, Arizona.*


The author's astroimaging setup shows the StarShoot Deep Space Video Camera attached to his 12.5-inch f/5 homebuilt Newtonian reflector. Chris Schur

Product information

Orion StarShoot Deep Space Video Camera

Imaging sensor: Mintron 72S85HN-EX-R color
Sensor size: 0.5 inch
Pixel array: 768x494
Video frame rate: 30 frames/second
Exposure range: 1⁄1,000 to 4 seconds
Weight: 8.7 ounces (247 grams)
Dimensions: 2.6 by 1.9 by 2.5 inches (66 by 48 by 64 millimeters)
Software compatibility: Windows XP/Vista/7
Includes: Video Capture Device, AC adapter, DC "cigarette lighter" adapter, video cable, CD-ROM
Price: $499.99
Contact
Orion Telescopes and Binoculars
89 Hangar Way
Watsonville, CA 95076
[w] www.telescope.com
[t] 800.447.1001

Astroimaging with the camera

Orion also designed its camera for use with the provided Video Capture Device to record AVI videos to a hard drive for later processing with various image-stacking software (not included). I found installing and using the supplied software difficult. After several days of trying, I finally succeeded only because my laptop had a live Internet connection.

And perhaps because the product is so new, I also discovered that Orion had not yet put any updates on its website. Hopefully, that won't be a problem by the time you read this review. Once the software was functioning, I imaged the Moon again and the bright star Arcturus and processed them with *Registax 6* without any problems.

A real-time winner

This camera does one thing extremely well — it displays celestial objects in color in real time. The sensitivity is sufficient to reveal most of the Messier objects through an 8-inch or larger telescope. Use it and you'll be a guaranteed hit at public events.

On the other hand, when I imaged with this camera, I was somewhat disappointed. For that kind of use, you might consider Orion's StarShoot Solar System Imager. In video mode, however, Orion's StarShoot Deep Space Video Camera offers a high "wow" factor, and it's a lot of fun to use.

Imaging the Cosmos
by Tony Hallas

Chasing the curve

Learn the limits of combining images to reduce noise.

Most fairy tales have their origin in the ancient past, but a select few have modern roots. In astrophotography, one such tale goes something like this: "If we just take enough frames of our subject matter and average them together, all the noise in our image will go away."

Similarly, we get recommendations to take "hundreds of dark frames" in the hope that we will have a "pure" master dark, the better to create a perfect picture.

Ain't gonna happen.

Looking at the graph at right, we notice something interesting. The level of noise does drop dramatically with the averaging of multiple frames at first, but then something strange happens: The curve begins to level out. Specifically, the improvement is substantial up to 16 frames, but after 25 frames, the improvement basically ends.

We call this boundary an "asymptote" — a certain number that a changing value approaches but never arrives at. Put another way, there comes a time beyond which further data collection achieves nothing in terms of noise reduction.

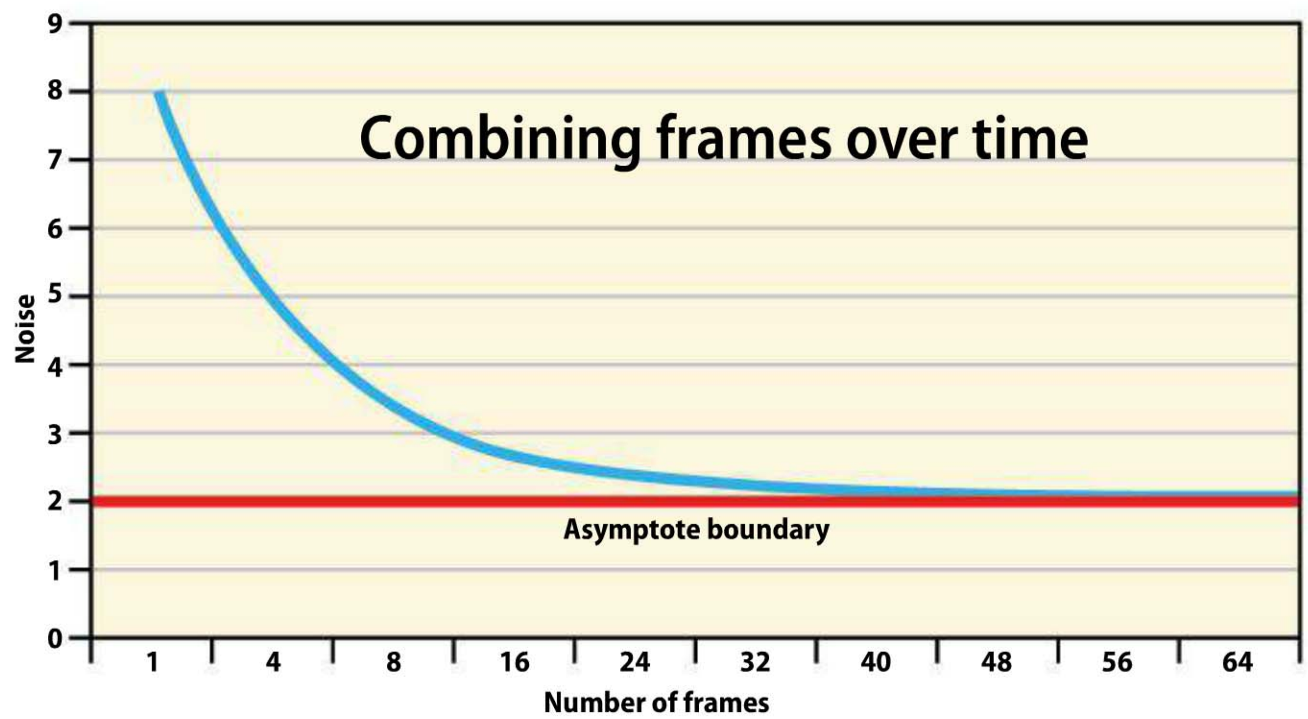
Related to this is the signal-to-noise formula: The improvement of signal to noise equals the square root of the number of frames combined. Four frames will thus double the signal over the noise, 16 frames will have a fourfold increase, and, theoretically, 25 frames will see a fivefold increase. Remember that at 25 frames, we're getting close to the asymptotic boundary, beyond which noise doesn't improve. Plus, the difference between four times and five times improvement is slim to begin with. Adding nine more frames accomplishes basically nothing.

In my experiments, I couldn't see any improvement after combining nine dark frames. Indeed, comparing the results of a three-frame dark and a 40-frame dark revealed no visible difference when I combined the light frames as a mean (average). See the photo comparison above for a visual reference.

Mixed in with all of this is the darkness of your sky, the nature of your subject matter, the accuracy of your tracking, the noise characteristics of your camera, and the optical integrity of your imaging device — all of which will have an effect on your final noise level. It's a lot to handle.

Remember, you can't take infinite frames. Make each one count, so that when you combine them to reduce noise, you bring as much as you can to the table. It is thus better to take the longest exposures that your equipment and sky will allow.

After image processing, use noise-reduction software on what noise remains to create the *illusion* of infinite data. That's how to get a real-life happy ending.



Combining a number of dark frames decreases noise initially, but after about 16 frames, the improvement fades as the noise level slowly approaches (but never reaches) the asymptotic boundary. *Astronomy*: Roen Kelly, after Tony Hallas

The rate of return for noise reduction diminishes quickly in the author's experiments. Note that the apparent noise level is identical between a three-frame dark (at left) and a 40-frame dark. Tony Hallas

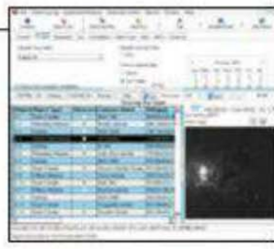
Browse the "Imaging the Cosmos" archive at www.Astronomy.com/Hallas.

New Products

See reports on 300+ products at www.Astronomy.com/equipment.

Attention manufacturers: To submit a product for this page, email **mbakich@astronomy.com**.

Observing software



Knightware
Cary, North Carolina
Knightware's *Deep-sky Planner 5.1* is an update that runs on Windows-based computers and allows users to create observing lists of targets from a database of more than one million objects.
Price: Free for *Deep-sky Planner 5* users, $73.95 for new-user CD, or $65 for new-user digital download
[e] sales@knightware.biz
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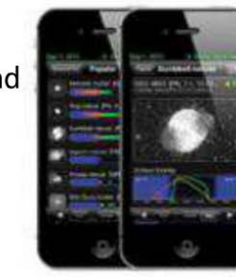

Observer Pro
Grants Pass, Oregon
With the *Observer Pro* application for the iPhone and iPod Touch, you can plan observing and imaging runs. Included charts let you know the best time to observe any of 14,000 deep-sky objects. It also has a red-screen night mode and observing-site comparisons.
Price: $9.99
[e] joshua@observerpro.com
[w] http://observerpro.com

Mechanical orrery

Armstrong Metalcrafts
Albany, Oregon
Armstrong Metalcrafts' Mechanical Paradox Orrery is an interpretation of the one that James Ferguson built in 1750. Brass, precision ball bearings, and mahogany make up each one. It measures about 10 inches (25cm) wide and roughly 4 inches (10cm) high. A 40-page booklet accompanies the orrery.
Price: $1,200
[e] sales@armstrongmetalcrafts.com
[w] www.armstrongmetalcrafts.com

Dew heater

Astrocrumb
Milford, Massachusetts
Astrocrumb's Omega Dew Terminator is a permanent dew heater for all Astrocrumb FilterSlide models when used in conjunction with standard dew controllers (like those from Kendrick or Thousand Oaks). It can be installed initially upon ordering a FilterSlide or later as an upgrade.
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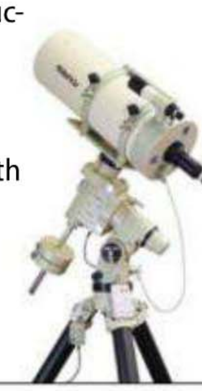
9.8-inch Dall-Kirkham telescope



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Houston, Texas
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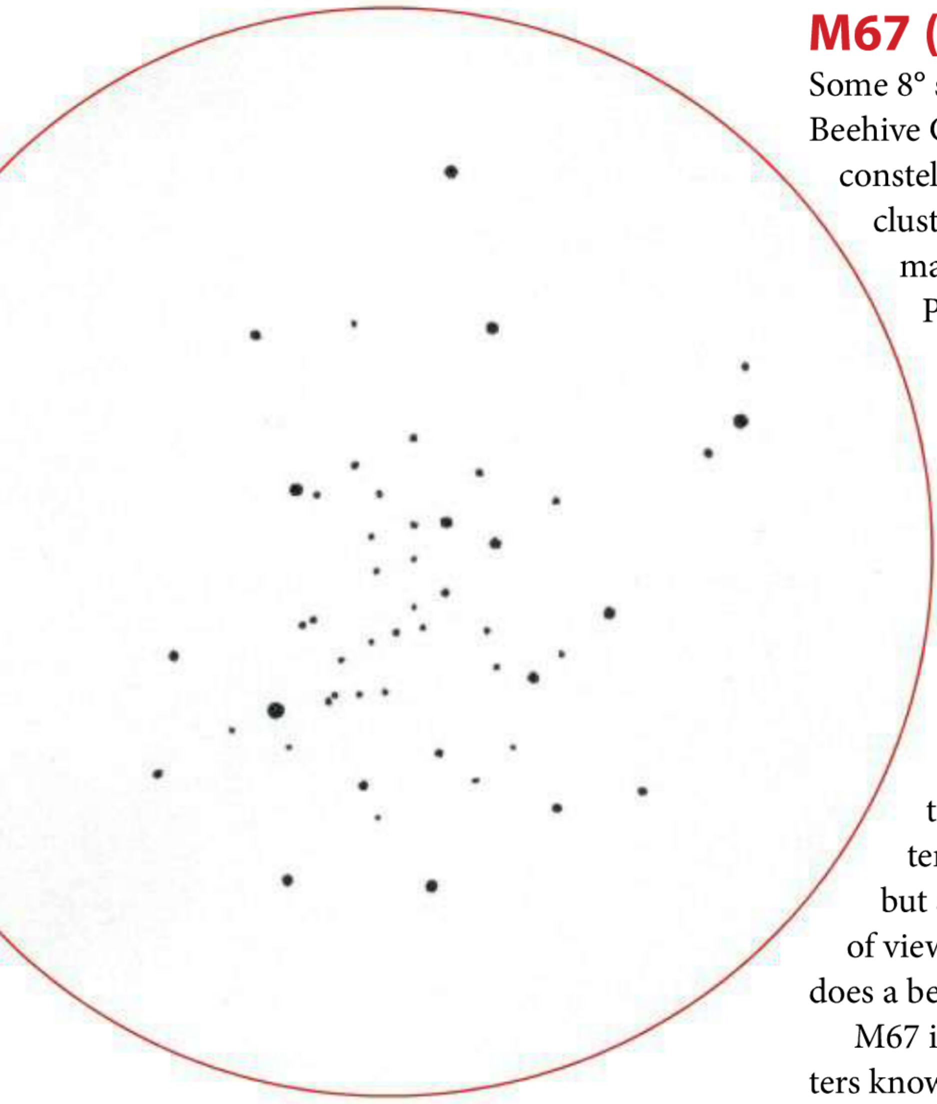
Deep-sky Showcase

Astronomy's editor sketches two of his favorite objects. **by David J. Eicher**

M67 and NGC 2775



M67 sketched by David J. Eicher using an 8-inch f/10 Celestron SCT at 50x.

M67 (NGC 2682)

Some 8° south and 2° east of the famous Beehive Cluster (M44) in Cancer lies the constellation's often overlooked open cluster, M67. This cluster provides a marvelous contrast to the Beehive. Packing 200 stars in a 30' diameter, M67 is a rich group of faint stars, the brightest only glowing at magnitude 9.7. The cluster's total magnitude is 6.9, which places it below the typical limit of naked-eye visibility.

M67 is a beautiful object. Two- and 3-inch reflectors show a patch of light speckled with a few tiny, gleaming stars. A 6-inch telescope at 120x resolves the cluster into dozens of faint pinpoints, but an overall haze pervades the field of view. A 10-inch telescope at 100x does a better job.

M67 is one of the oldest open star clusters known, estimated to be 3.2 billion years old. This explains why its many stars are so faint and yellow, orange, and red in hue.

M67

Richard McCoy

Designations: M67, NGC 2682
Position: 8h51m, 11°49' (2000.0)
Constellation: Cancer
Magnitude: 6.9
Size: 30'
Distance: 3,200 light-years

Only NGC 6791 in Lyra, Melotte 66 in Puppis, NGC 188 in Cepheus, and a few other clusters are older. M67 lies 3,200 light-years away, five times more distant than its neighbor the Beehive Cluster. Most open clusters are torn apart more quickly as they orbit the galactic center, so M67 and others like it are rarities and give us an unusual view of something special in the cosmos.

NGC 2775

Adam Block/Mount Lemmon SkyCenter/University of Arizona

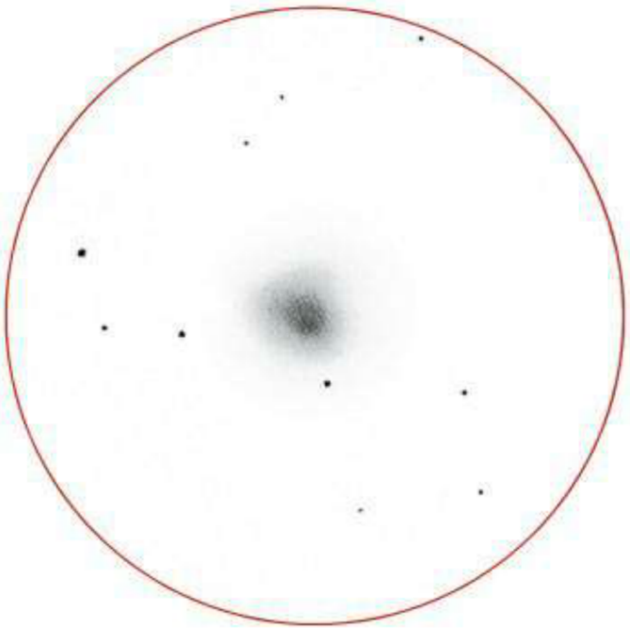
Designation: NGC 2775
Position: 9h10m, 7°02' (2000.0)
Constellation: Cancer
Magnitude: 10.1
Size: 3.1' by 2.5'
Distance: 55 million light-years

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 35 years.*

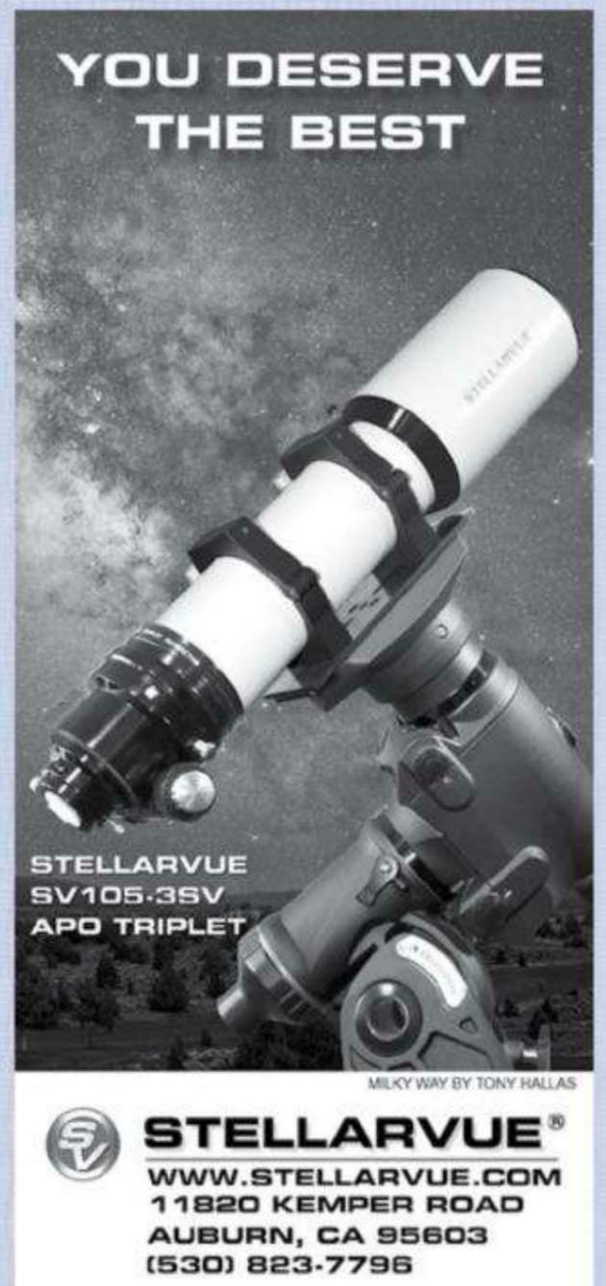
NGC 2775

Near the Cancer-Hydra border, 6° southeast of M67, is faint galaxy NGC 2775, a 10th-magnitude spiral measuring 3.1' by 2.5' across. The galaxy appears as a nebulous streak of pale light through a 6-inch scope at 100x.

A large telescope begins to bring out a little detail in this galaxy. A 17.5-inch telescope reveals a faint circular glow with a halo of nebulosity surrounding it in a barren star field. The view is not magnificent, but when you realize you're soaking in the light from a small galaxy that's 55 million light-years away — about the same distance as the Coma-Virgo galaxy cluster — it's impressive to know that this ball of light represents the collective photons from 300 or 400 billion stars. What magnificent things are going on inside this galaxy that we'll never know about? Is it possible that many strange beings are looking back toward the Milky Way with their instruments as you are looking at their home galaxy? We'll never know.



NGC 2775 sketched by David J. Eicher using a 17.5-inch f/4.5 reflector at 71x.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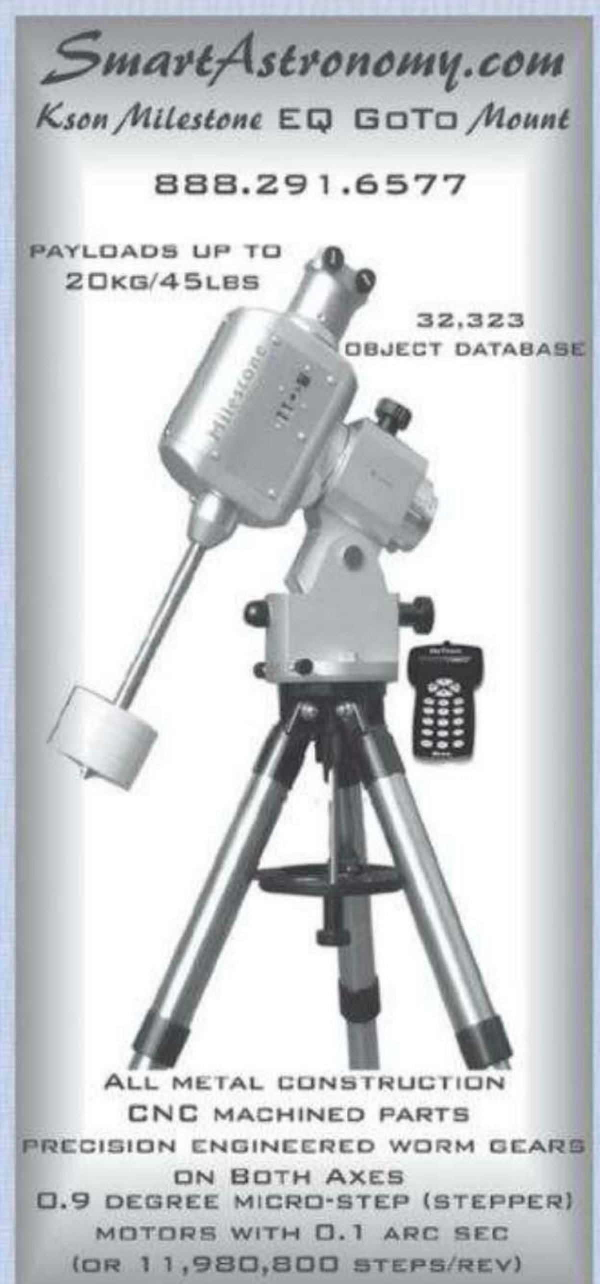
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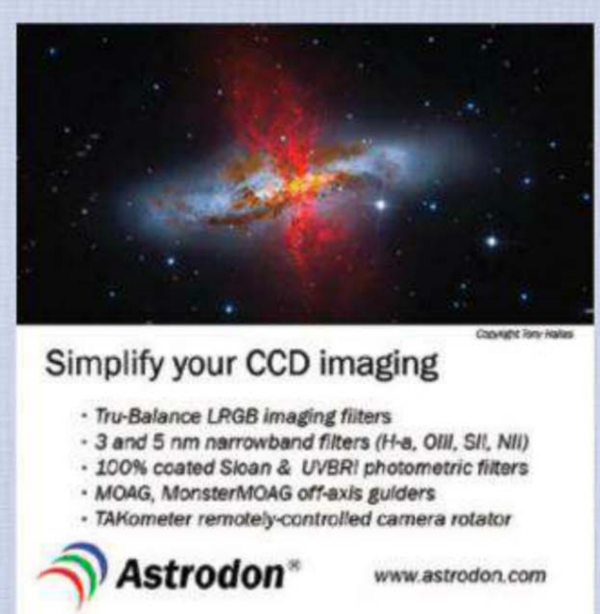
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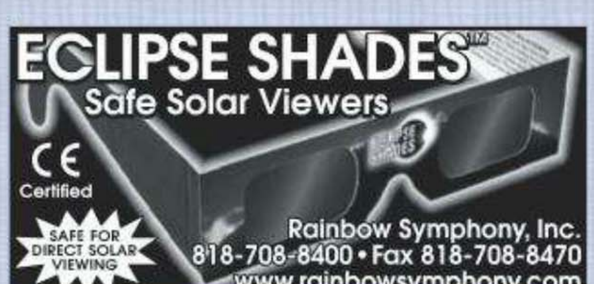
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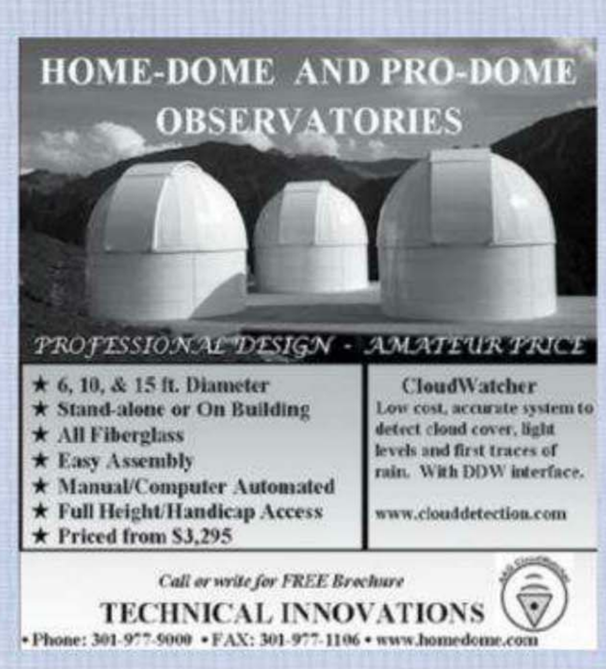
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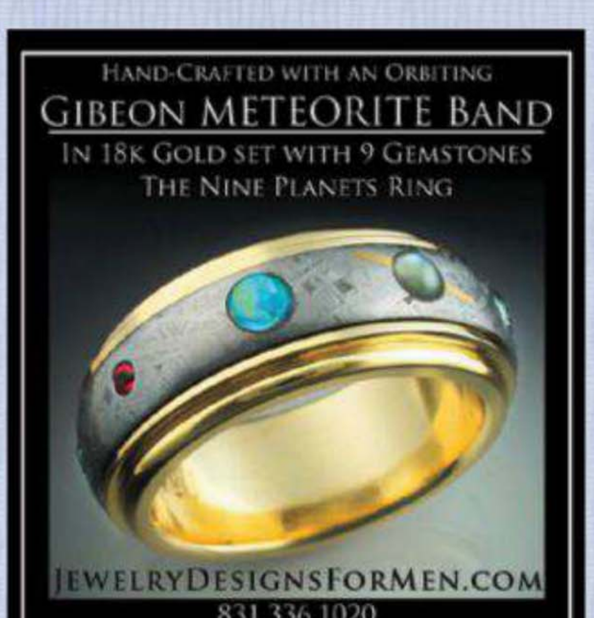
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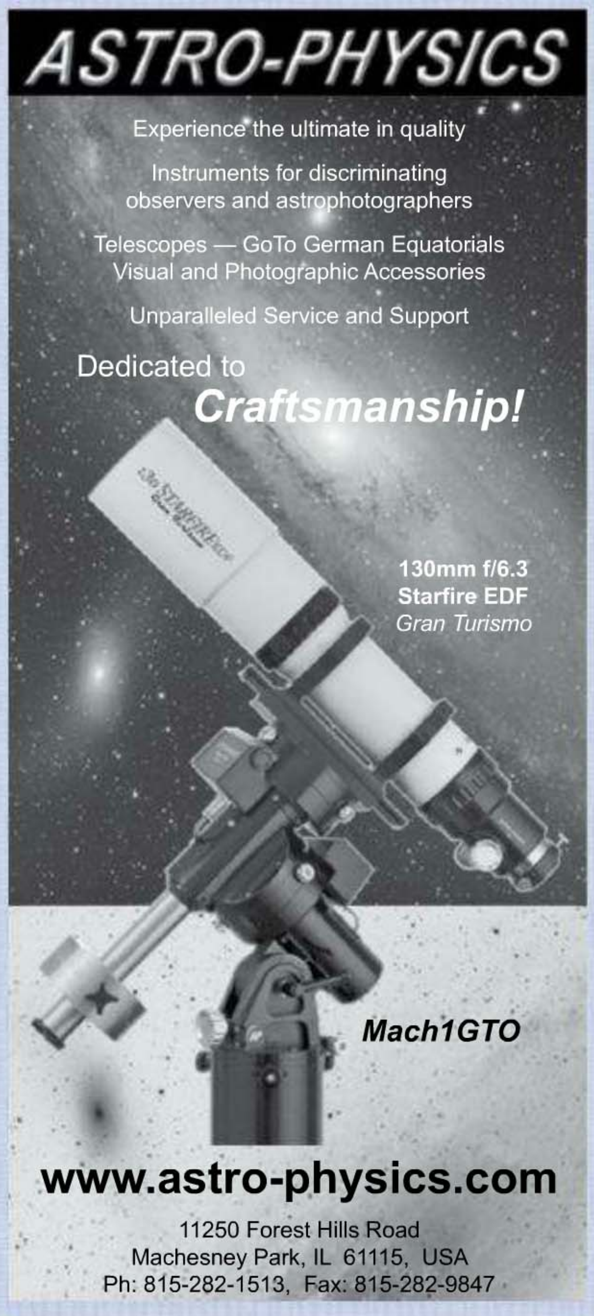
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COMING UP IN OUR NEXT ISSUE

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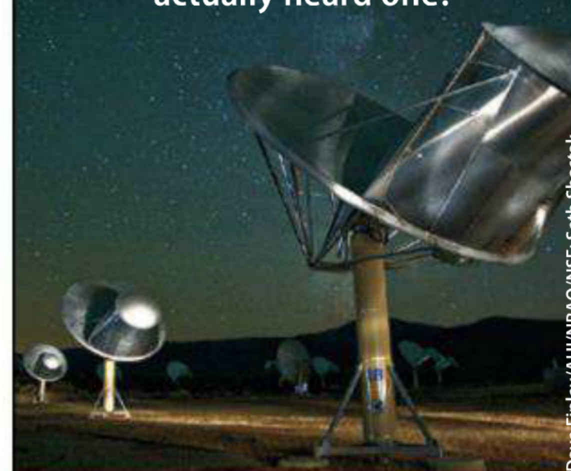
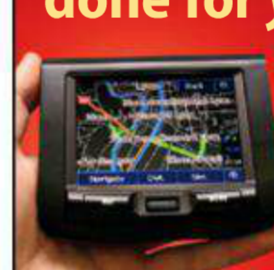
Scientists have been listening for signals from extraterrestrial civilizations for decades, but what would they do if they actually heard one?



Dave Finley/AUI/NRAO/NSF; Seth Shostak

What has astronomy done for *you* lately?



Wireless Internet and GPS are just two technologies that stem from astronomy

Olaru Radian-Alexandru/Photos.com

Illustrated:

Inside nature's fundamental forces

NSO/AURA/NSF

PLUS

- Explore 10 spring galaxies
- 10 great spring binocular sights
- View May's unusual solar eclipse
- How London created a big-city astro club
- *Astronomy* tests Coronado's SolarMax II 60 Telescope

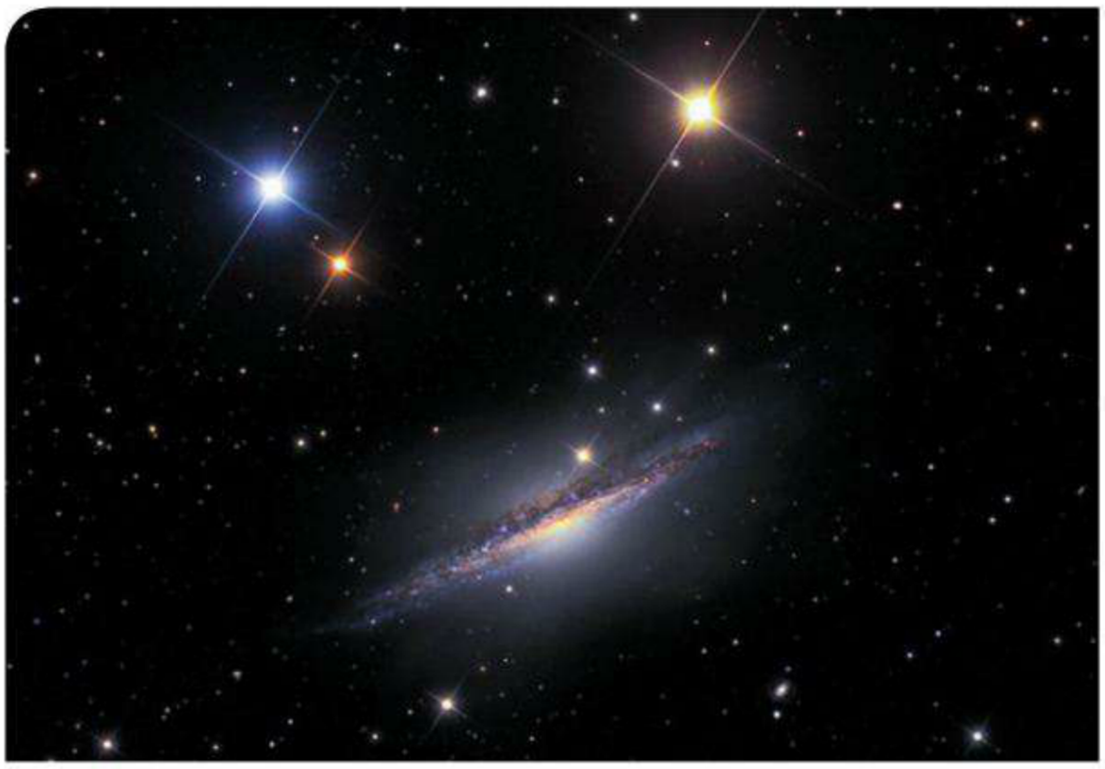
Astronomy magazine

reader gallery

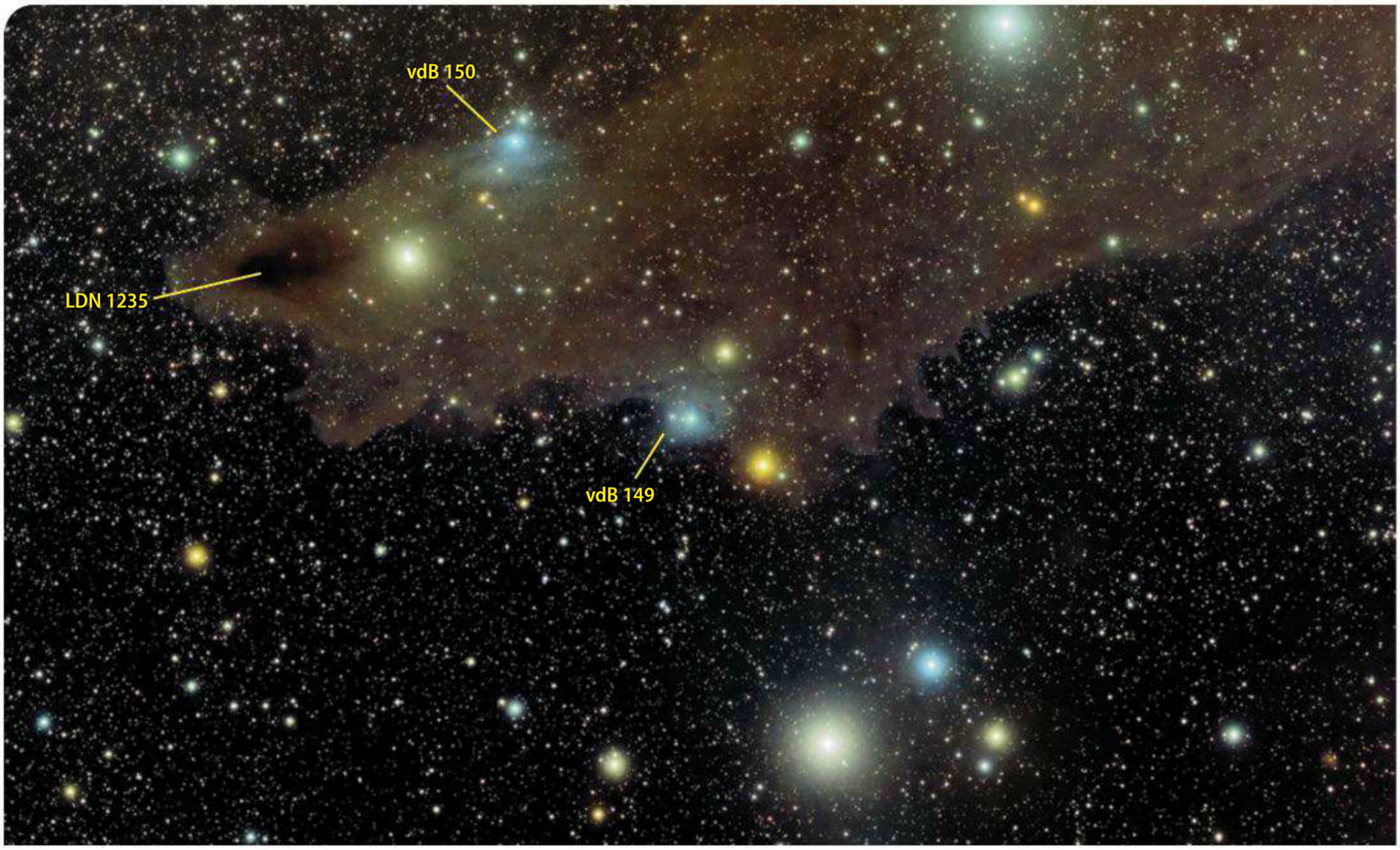
▲ **Total lunar eclipse** (Canon EOS 60D DSLR, Canon EF 17–40mm lens set at f/4, ISO 2000, thirty-eight 0.6-second exposures, taken December 10, 2011, beginning at 14h24m11s UT and ending at 16h14m56s UT) • Farzad Ashkar, Shiraz, Iran

Earth's shadow falls on the Moon

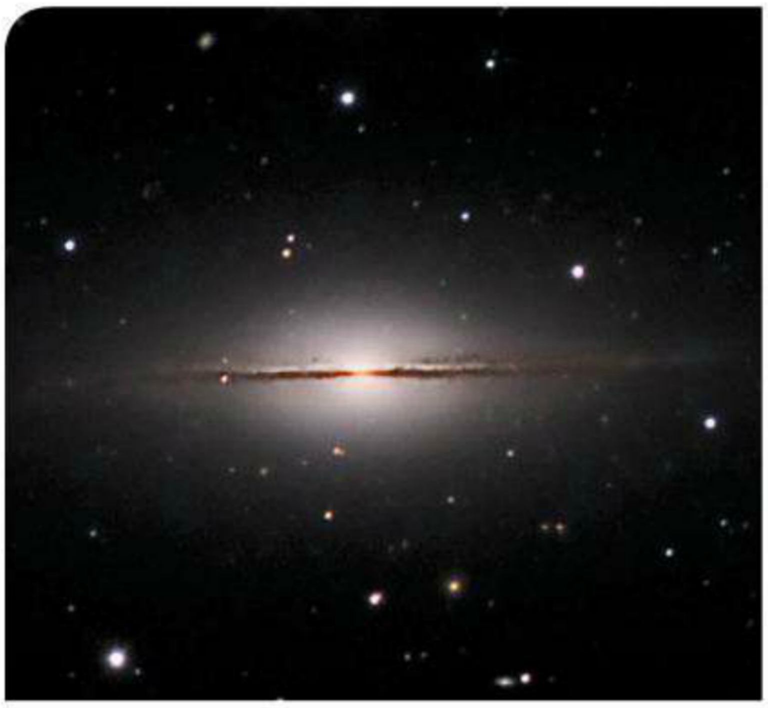
Persepolis, a UNESCO World Heritage Site, was the ceremonial capital of the First Persian Empire. Now within the boundaries of Iran — about 43.5 miles (70 kilometers) from Shiraz — it dates from around 515 B.C. The imager used the site to help frame December's total lunar eclipse. During a span of 1 hour and 50 minutes, the Moon rose from the lower left almost totally eclipsed and brightened as it moved out of Earth's dark inner shadow (and behind some thin clouds). The bright dot seen as multiple images to the right of the Moon is the ruddy star Aldebaran (Alpha [α] Tauri). This was the last total lunar eclipse until April 15, 2014.



▲ **Barred spiral galaxy NGC 1055** in Cetus makes a nice triangle with the magnitude 7.6 blue star SAO 110692 and magnitude 6.7 SAO 110689, which shines with a yellow hue. (20-inch RC Optical Systems Ritchey-Chrétien reflector at f/8.3, Apogee Alta U9000 CCD camera, LRGB image with exposures of 440, 120, 120, and 140 minutes, respectively) • Ken Crawford, Camino, California

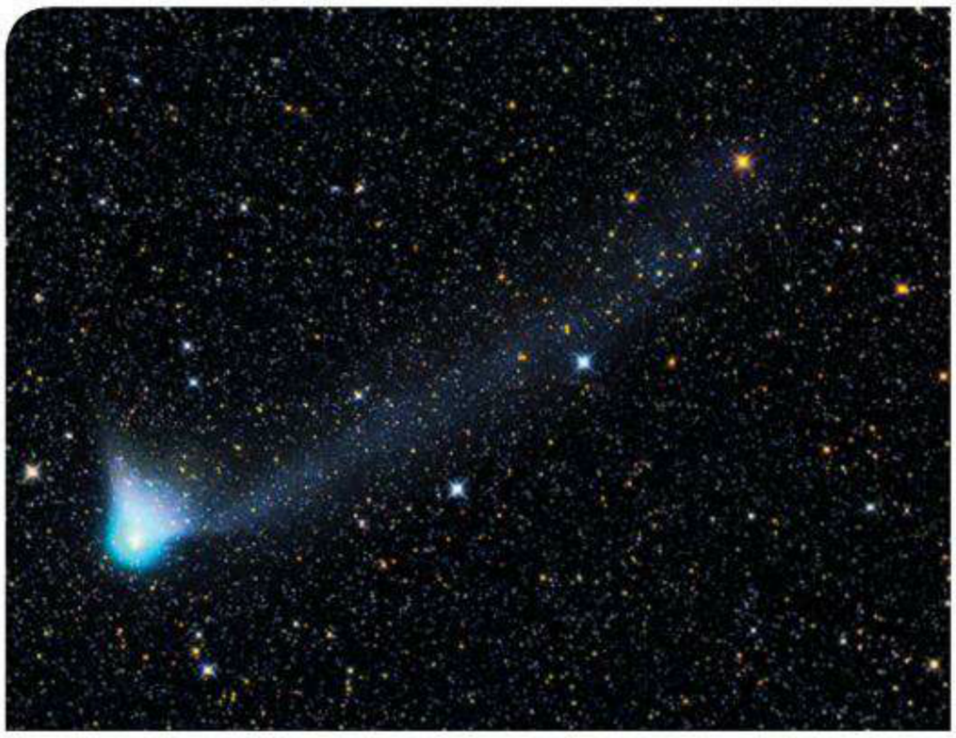


▲ **Two reflection nebulae,** van den Bergh 149 and vdB 150, lie in a rich field in Cepheus the King dominated by dark nebulosity and colorful stars. vdB 149 surrounds a magnitude 9.7 star, and vdB 150 envelops one of magnitude 8.3. (5.2-inch Takahashi TOA-130 apochromatic refractor at f/6, SBIG STL-11000M CCD camera, 6.5 hours of luminance exposures combined with 4.5 total hours of exposures through RGB filters) • Alistair Symon, Marana, Arizona



▲ **Spiral galaxy NGC 7814,** also known as Caldwell 43, glows at magnitude 10.6 in the constellation Pegasus the Winged Horse. It measures 6.0' by 2.5'. (14-inch Officina Stellare RC-360AST Ritchey-Chrétien Cassegrain reflector at f/8, Apogee Alta U16M CCD camera, LRGB image with exposures of 160, 90, 90, and 90 minutes, respectively) • Bob Fera, Foresthill, California

◀ **Ellis-Grayson-Bond 6** is a faint planetary nebula in Leo that measures 11' by 13'. It lies 1,500 light-years away and is approximately 60,000 years old. (16-inch RC Optical Systems Ritchey-Chrétien reflector at f/8.9, Apogee Alta U16M CCD camera, 9 hours of Hα exposures stacked with 9.5 hours of OIII and 1 hour [total] of RGB exposures) • Don Goldman, Orangevale, California



▲ **Comet C/2009 P1 (Garradd)** shone near 8th magnitude in late November 2011 as it traversed the constellation Hercules. Note the long blue ion tail stretching to the upper right and just a hint of the yellowish dust tail. (8-inch Astro Systeme Austria ASA H8 hyperbolic astrograph at f/3, FLI PL-16803 CCD camera, LRGB image with 9-minute exposures through each filter, taken November 28, 2011, at 17h05m UT from Sandl, Austria) • Gerald Rhemann, Vienna, Austria

▲ **Spiral galaxy M90** shines at magnitude 9.5 in the constellation Virgo the Maiden. The galaxy measures an impressive 10.5' by 4.4', but its spiral arms wrap so tightly around it that you'll need a 20-inch or larger telescope to resolve them. (16-inch Meade LX200 Schmidt-Cassegrain telescope at f/6.3 and f/10, SBIG ST-8E CCD camera, LRGB image with exposures of 105, 20, 20, and 20 minutes, respectively) • Paul and Daniel Koblas/Adam Block/NOAO/AURA/NSF

▲ **This brilliant Geminid meteor** flashed over Mount Whitney while the imager was shooting in the Sierra Nevada Mountains in California. With an elevation of 14,505 feet (4,421 meters), Mount Whitney ranks as the highest point in the contiguous United States. (Nikon D300s DSLR, telephoto lens set to 135mm and f/3.8, ISO 1000, 5-second exposure, taken December 14, 2011, at 3:35 A.M. PST) • Tony Rowell, Bishop, California

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to readergallery@astronomy.com.

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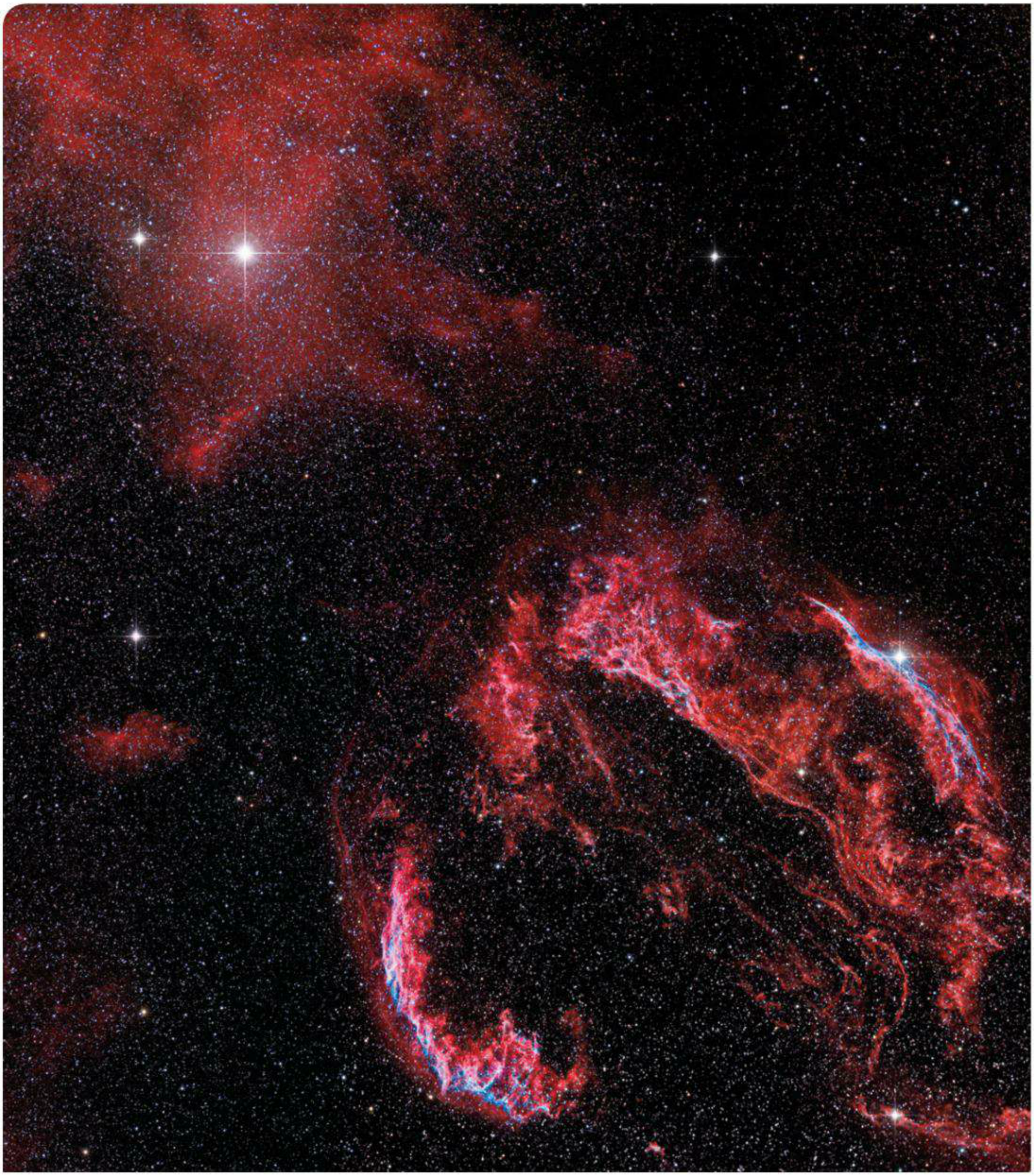


▲ **This two-panel mosaic of the Veil Nebula** (NGC 6960/NGC 6992–95), the complex to the lower right, shows its many parts. The imager also wanted to include the magnitude 2.5 star Gienah (Epsilon [ε] Cygni), which lies to the Veil's upper left. In doing so, he also found lots of additional reddish emission nebulosity surrounding it. (4-inch Takahashi FSQ-106EDX apochromatic refractor at f/3.63, SBIG STL-11000M CCD camera, HαRGB image with exposures of 90, 15, 15, and 15 minutes per panel, respectively) • John A. Davis, Dallas, Texas

The Cosmic Grid

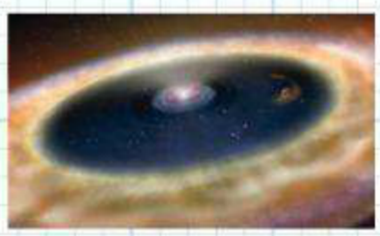
All things high, low, weird, and wonderful in astronomy and space science. **by Bill Andrews**

WEIRD

Next, warp speed?
Nature reports that scientists have replicated the physics-defying finding that neutrinos can travel faster than light, making it harder to pretend that it's not super exciting.

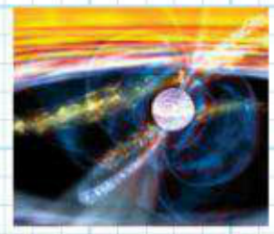
Smile from space
A meteorite discovered near Conception, Missouri, turns out to be a rare pallasite, which apparently produces feelings of bliss.

Light touch
NASA spends $100,000 to research functional tractor beams, perhaps wanting to increase its pull with Congress.



Oops observation
Astronomers discover a planet "in the process of forming around its star," presumably because they forgot to knock before coming in.

No wonder!
Penn State releases a story headlined, "Nonterrestrial artifacts hard to find," just in case there was any doubt.



Spooky space science
A potential NASA mission would study the interiors of neutron stars, or, in press release talk, "Reveal the Hearts of Undead Stars."

Phobos-scream
Possibly adding injury to insult, the failed Russian Phobos-Grunt mission posed a potential danger when it crash-landed back on Earth.

Going ballistic
More dangerous than Phobos-Grunt's return might be the wrath of Russian President Dmitry Medvedev, who wants to "punish those guilty" for the probe's failure.

Spookier space science
"Very First Stars Not Monstrous," NASA announces, answering one question but raising many more.

HOT

NOT

Cosmic considerations
The New York Times reports, "NASA is Considering Fuel Depots in the Skies." Don't get too excited, though; "considering" can mean a lot.

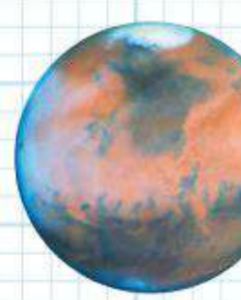
Wrong wraps
A Dutch astronomer says depictions of the Moon in holiday illustrations and wrapping paper are often inaccurate. Somehow, I'd never noticed.

Question answered
The White House responds to E.T.-related petitions, saying there's "no evidence that any life exists outside our planet." Well, I'm sure *that*'ll satisfy everyone!

It's about time
Neil Armstrong, Buzz Aldrin, Michael Collins, and John Glenn receive Congressional Gold Medals for their space exploits in the 1960s. Boy, Congress really does move slowly.

Elementally, my dear
Elements 110, 111, and 112 officially receive the names darmstadtium, roentgenium, and copernicium, so I guess Newtonium and Keplerium will have to wait.

Finances over physics?
A 2011 survey calls NASA the fifth-best place to work in the federal government, with the Federal Deposit Insurance Corporation winning the top spot. I suspect cheating.



Mars plans imperiled
Financial concerns threaten the future of current Mars exploration plans. "Aren't we ever gonna get there?" ask the 1970s.

Launch laurels
NASA launches a "multi-talented" Earth-studying satellite, proving that even the agency's hardware works harder than 90 percent of the workforce.

End of an era
Oil field workers begin training in NASA's giant pool, the Neutral Buoyancy Laboratory, because of the space agency's decreased need for spacewalk training.

PREDICTABLE

PHOTOGRAPHS: NASA (Next, warp speed?); Dave Gheesling (Smile from space); NASA/Dr. Paul Stysley (Light touch); Karen L. Teramura/UH IfA (Oops observation); NASA (Spooky space science); Lavochkin Association (Phobos-scream); Kremlin.ru (Going ballistic); © 2012 JupiterImages Corporation (Spookier space science); NASA/KSC (Finances over physics?); Philip James (University of Toledo)/Steven Lee (University of Colorado)/NASA (Mars plans imperiled); NASA/Bill Ingalls (Launch laurels); NASA (End of an era); NASA (Cosmic considerations); NASA/JPL, Dmitry Rukhlenko/Photos.com (Wrong wraps); UpstateNYer (Question answered); NASA/Stephanie Schierholz (It's about time)

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BY MARTIN GEORGE

Venus transits the Sun

As twilight fades during June, a quick look to the northern sky reveals two prominent planets: Mars and Saturn. **Mars** appears against the backdrop of Leo, an intruder lurking just above the Lion's rear legs. At magnitude 0.7, the Red Planet shines nearly twice as bright as Leo's luminary, Regulus. By late June, Mars' eastward motion relative to the starry background carries it into Virgo.

The best views of Mars through a telescope come early this month, when the planet lies nearer Earth and appears larger. Its disk then spans 7.9", a value that drops to 6.6" by month's end.

Saturn lies east of Mars and some 5° below Virgo's brightest star, Spica. (At magnitude 0.6, Saturn appears noticeably brighter than the star.) The ringed planet is beautifully positioned during early evening hours, appearing more than halfway to the zenith after sunset.

Saturn's appearance through a telescope never fails to impress. Its rings currently span 41" and tilt 13° to our line of sight, while the planet's relatively bland disk measures 18" across. During moments of steady seeing, watch for the dark gap near the rings' outer edge known as Cassini's Division. A handful of moons also shows up, led by 8th-magnitude Titan.

From mid-June on, **Mercury** puts on a nice show in the evening sky. It becomes easier to see toward the end of the month as it approaches greatest elongation from the Sun in early July. By June 30, the innermost planet appears 15° high 30 minutes after sunset and a still-respectable 10° high half an hour later. Through a telescope, it then displays an 8"-diameter disk that's slightly less than half-lit. It will grow larger and show a thinner crescent phase early next month.

Jupiter returns to the morning sky in June. Shining at magnitude –2.0, it stands out in the eastern sky during twilight, climbing significantly higher and becoming easier to see as the month progresses. Jupiter lies among the background stars of Taurus the Bull, just 5° from the magnificent Pleiades star cluster (M45). Be sure to view these two through binoculars once they climb higher in a darker sky near June's close.

A telescope reveals Jupiter's disk, which spans 34" at month's end, but not a lot of detail. Expect better views of the planet's dynamic atmosphere as the world climbs higher in the predawn sky in the coming months. This month, spend your telescope time watching Jupiter's four bright Galilean moons, which show up even through the smallest instruments.

In the second half of June, brilliant **Venus** joins Jupiter in the morning sky. The two brightest planets approach within 5° of each other by month's end. Venus then gleams at magnitude –4.6 and its 45"-diameter disk shows a thin crescent phase.

The biggest astronomical attraction this month also involves Venus. On June 5/6, the inner planet appears in silhouette against the Sun's disk. This **transit of Venus** marks the second such event of the past eight years and the last one until 2117. Depending on your location, the transit begins within a few minutes of 22h10m UT June 5 and ends close to 4h50m UT June 6.

Australasia and the South Pacific Ocean are the best Southern Hemisphere locations from which to view this event. From Sydney, Australia, the transit begins at 22h16m UT and ends at 4h44m UT (8:16 A.M. to 2:44 P.M. local time June 6). Remember not to look directly at the Sun without using an approved solar filter.

Similar regions of the world will have the best views of the June 4 **partial lunar eclipse**. It begins at 10h00m UT and ends at 12h07m UT, with maximum eclipse occurring at 11h04m UT. Earth's dark shadow then obscures 38 percent of the Moon's diameter.

The starry sky

When avid stargazers plan their visits to the Southern Hemisphere, many aim for the winter months. Although the Milky Way appears at its best around midnight this month, the constellation Crux the Southern Cross now lies highest in the evening sky. Visitors from the world's northern regions delight in seeing the Cross appear as it does on the flags of many southern countries, including those of Australia and New Zealand.

But there's far more than the Cross in June's evening sky. Shift your gaze east of Crux to find Scorpius the Scorpion, whose head slants up and to the left as the sky darkens. Binoculars afford great views of Scorpius' tail, which I consider to be one of the most striking parts of the southern sky. Lambda (λ) and Upsilon (υ) Scorpii make a prominent pair that forms the Scorpion's stinger.

Just below the stinger lies one of the finest binocular objects in the sky: the open star cluster M7. It is the southernmost object in Charles Messier's famous catalog of deep-sky wonders. M7 looks like a fuzzy patch to unaided eyes, but binoculars easily resolve it. Also look near the bend in the Scorpion's tail for the magnificent binocular cluster NGC 6231.

Countless stars litter the Milky Way from Scorpius through Norma, southern Centaurus, and into the Cross. Continue sweeping westward just beyond the Cross and you'll uncover a wonderful smorgasbord of clusters and nebulae in the northeastern corner of Carina the Keel.

My favorite is the open cluster NGC 3532, which appears on the opposite side of Crux from the conspicuous stellar duo of Alpha (α) and Beta (β) Centauri. I often start off observing sessions for novice stargazers with this lovely cluster.

StarDome

The all-sky map shows how the sky looks at:
9 P.M. June 1
8 P.M. June 15
7 P.M. June 30

Planets are shown at midmonth

How to use t
latitud
south

Magnitudes
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

his map: This map portrays the sky as seen near 30° south
e. Located inside the border are the four directions: north,
, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly

June 2012

Calendar of events

1 The Moon passes 7° south of Saturn, 5h UT

3 The Moon is at perigee (358,485 kilometers from Earth), 13h16m UT

4 Full Moon occurs at 11h12m UT; partial lunar eclipse

5 Neptune is stationary, 6h UT

6 Venus is in inferior conjunction, 1h UT; transits the Sun

The Moon passes 1.0° south of Pluto, 3h UT

10 The Moon passes 6° north of Neptune, 5h UT

11 Last Quarter Moon occurs at 10h41m UT

12 The Moon passes 0.8° north of asteroid Pallas, 17h UT

13 The Moon passes 5° north of Uranus, 1h UT

15 Venus passes 4° north of Aldebaran, 6h UT

16 The Moon is at apogee (405,787 kilometers from Earth), 1h24m UT

17 The Moon passes 1.1° north of Jupiter, 8h UT

18 The Moon passes 2° north of Venus, 1h UT

19 New Moon occurs at 15h02m UT

20 June solstice occurs at 23h09m UT

21 Mercury passes 5° south of Pollux, 18h UT

The Moon passes 6° south of Mercury, 19h UT

26 Saturn is stationary, 9h UT

The Moon passes 6° south of Mars, 15h UT

27 First Quarter Moon occurs at 3h30m UT

Venus is stationary, 4h UT

28 The Moon passes 6° south of Saturn, 12h UT

Pluto is at opposition, 15h UT

For definitions of terms, log onto www.Astronomy.com/glossary.